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Institute for Research on Educational Finance and Governance

SCHOOL OF EDUCATION STANFORD UNIVERSITY

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THE EDUCATIONAL IMPLICATIONS OF HIGH TECHNOLOGY

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The Institute for Research on Educational Finance and Governance is a Research and Development Center of the National Institute of Education (NIE) and is authorized and funded under Section 405 of the General Education Provisions Act as amended by Section 403 of the Education Amendments of 1976 (P.L. 94-482). The Institute is administered through the School of Education at Stanford University and is located in the Center for Educational Research at Stanford (CERAS).

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Abstract

Many business leaders, government officials, and educators believe that high technology will dominate America's economic future, will upgrade the skill requirements of future jobs, and will require a transformation of our educational system to meet these needs. Despite the popularity of these beliefs, available evidence contradicts them: the expansion of the lowest skilled jobs in the American economy will vastly outstrip the growth of high technology ones; and the proliferation of high technology industries and their products is far more likely to reduce the skill requirements of jobs in the U.S. economy than to upgrade them. Nonetheless, the educational system should strengthen the analytical and communicative skills of students, not because of the needs of high technology, but because such skills will help them deal with the changing political, economic, social, and cultural institutions they will face in their adult lives.

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New advances in technology--in genetic engineering, in robotics, and particularly in computers--are transforming the lives of Americans in the home and the workplace. While the micro-computer has signalled the arrival of "high-technology" in the home, many observers believe that its influence in the workplace will be even more profound. Not only do industries producing micro-processors, robots, and the fruits of bio-technology promise rapid growth in sales and employment, but micro-computers and robots are also expected to transform other industries and occupations throughout the economy. One observer predicted that 40 to 50 percent of all American workers will be using electronic terminals by 1990 (Giuliano 1982, p. 152).

Government leaders, Republican and Democrat alike, see the growth of high-technology as one key to solving America's current economic problems. As President Reagan said in his State of the Union Address on January 25, 1982:

> ...as surely as Americans' pioneer spirit made us the industrial giant of the 20th century, the same pioneer spirit today is opening up another vast frontier of opportunity--the frontier of high technology. In conquering this frontier, we cannot write off our traditional industries, but must develop the skills and industries that will make us a pioneer of tomorrow.

Business leaders have echoed this sentiment, calling on the educational system to make the changes necessary to provide enough skilled workers to fuel the growth of high technology. As Steven Jobs, co-founder of Apple Computer, recently stated in a speech at Stanford University: "A massive retraining effort by government and private industry could alleviate the problem of job skill obsolescence created by the expanding computer industry" (Stanford Daily 1983).

Policymakers have proposed vast changes in the educational system to respond to these challenges. The proposed changes are based on the belief that our high-technology future will require workers with more sophisticated job skills. A recent publication from the Education Commission of the States (1982) exemplifies this widespread belief:

> Occupational growth throughout the 1980s is projected to expand most rapidly in the higher-skilled, technical occupations. Tomorrow's workers will likely need improved skills in the selection and communication of information. Many of today's skills considered to be of a "higher" level are the potential basic skills of tomorrow (p. 1).

Such beliefs have prompted proposals to upgrade math and science education in our nation's secondary schools, to place computers in all elementary and secondary schools, and to generate $1 billion in new support for high-technology education (Botkin, Dimancescu, and Stata, 1983).

These beliefs are based on two assumptions. First, future job growth in the United States will favor professional and technical level jobs--such as engineers and computer programmers--that require considerable education and sophisticated training in computer-related areas. Second, high technology will upgrade the skill requirements of existing jobs because workers in those jobs will work increasingly with technologically sophisticated equipment, such as computers.

Despite the widespread propagation of these assumptions, both are contradicted by available evidence. Most new jobs will not be in high technology occupations, nor will the application of high technology in existing jobs require a vast upgrading of the skills of the American labor force. To the contrary, the expansion of the lowest skilled jobs in the American economy will vastly outstrip the growth of high technology ones. And the proliferation of high technology industries and their products is far more likely to reduce the skill requirements for jobs in the U.S. economy than to upgrade them.

In the remainder of this paper we will examine the two common assumptions about high technology and the supporting evidence in greater detail. We will then discuss the educational implications of our high-technology future.

Future Employment Growth

To what degree will high technology jobs dominate future employment growth? Accurate predictions on the composition of future employment depend on the analysis of many factors. These include such influences as economic growth, labor force demography, foreign trade movements (many of which are influenced by changes in international exchange rates), technological breakthroughs, and decisions of multi-national organizations with respect to the international rationalization of production. Many of these factors are difficult to predict because they are subject to political and economic vagaries on a world scale.

While no methodology is likely to provide completely accurate results, those that consider a large number of pertinent influences are likely to be superior to simple extrapolations or other uncomplicated projections. In this respect, the estimates of the Bureau of Labor Statistics (BLS) of the U. S. Department of Labor represent some of the most refined attempts to project the growth and composition of future employment.

Since the 1960s BLS has periodically conducted a series of projection studies based on an economic growth model. Over the last two decades "the methodology has been continually modified to include greater industrial detail, other models, more rigorous analytical techniques, a more automatic system for processing calculations, and broader coverage including labor force and occupations in the current version" (Oliver 1982, p. 1). The methodology incorporates several assumptions about growth in the labor force, economic output, and productivity. Further, to allow for uncertainty, recent projections--for the year 1990--are based on three different scenarios regarding the growth of these various factors. The more optimistic projections assume high growth rates in economic output and productivity, while the more conservative projections assume lower growth rates.

The employment projections are based on occupational employment patterns within detailed industries in 1978, projected employment patterns within these industries in 1990, and projected total employment within each industry based on the economic projections. It is important to note that employment growth refers only to new jobs added to the economy rather than job openings. Job openings will be much higher. BLS estimates that employment growth will account for only one-third of total job openings between 1978 and 1990 (excluding openings due to workers' changing jobs), with the remaining two-thirds due to the replacement of workers in existing jobs who withdraw from the labor force because of death, retirement, or other reasons (U.S. Bureau of Labor Statistics 1980, p. 6).

We will limit our discussion to employment growth resulting from projected creation of new jobs using the BLS figures based on assumptions of modest growth rates. According to these figures, employment will increase by 22 million or 23 percent between 1978 and 1990 (Table 1). The fastest growing job categories in relative terms--percentage change between 1978 and 1990--include several high technology areas. This projected expansion apparently has led to the commonplace assumption that aggregate job growth will be biased toward high technology occupations. Of the five fastest growing occupations, three--data processing machine mechanics, computer systems analysts, and computer operators--deal with high-technology products. Employment in these five occupations is projected to increase by over 100 percent, more than four times the employment growth rate in all occupations.

Such percentage changes are misleading, however. The total number of new jobs generated in these and other high technology occupations will be vastly outweighed by employment growth in other areas. Slower-growing occupations with a large employment base are expected to contribute far more jobs to the economy than high technology occupations. Of the 20 occupations expected to generate the most jobs in the economy during this period, not one is related to high technology. As Table 1 shows, the five occupations expected to produce the most new jobs are all in low skilled areas: janitors, nurses' aides, sales clerks, cashiers, and waiters and waitresses. These five jobs alone will account for 13 percent of the total employment growth between 1978 and 1990. Only 3 or 4 of the "top 20" occupations in terms of total contribution to job growth require education beyond the secondary level, and only two require a college degree (teaching and nursing).

This picture is further reinforced by examination of individual high technology job categories. While jobs for computer systems analysts will increase by over 100 percent between 1978 and 1990, only 200,000 new jobs will be created. In contrast, there will be over 600,000 new jobs for janitors and sextons. In fact, more new jobs for janitors will be created than new jobs in all the five occupations with the highest relative growth rates. Consider another example: about 150,000 new jobs for computer programmers are expected to emerge during this 12 year period, a level of growth vastly outpaced by the 800,000 new jobs expected for fast food workers and kitchen helpers.

Employment growth for the economy as a whole will favor low and middle level occupations. While employment in professional and technical occupations is expected to increase by 20 percent for the twelve year period, this growth rate is lower than in either of the two preceding decades (Table 2). Employment in all professional and managerial occupations increased by 36 percent between 1960 and 1970, and 45 percent between 1970 and 1980. But it is projected to increase by only 28 percent between 1978 and 1990. Clerical and service occupations will account for 40 percent of the employment growth during this period.

Revised BLS estimates show that high technology occupations, as a group, will account for only 7 percent of all new jobs between 1980 and 1990 (Coleman 1982). BLS forecasts are further supported by other government analyses, such as those by the Department of Defense (Choate 1983).

In summary, government estimates suggest that employment growth will favor jobs that require little or no training beyond the high school level. Although employment in high technology occupations will increase quickly in percentage terms over this decade, the contribution of these jobs to total employment growth will be quite small.

The Impact of Technology on Existing Jobs

While the growth of high technology occupations will not have a major impact on overall employment growth in the foreseeable future, high technology will have a profound impact on many jobs in the economy. Increasingly workers in a variety of work settings will find their jobs altered by sophisticated computer technologies. Secretaries will work with word processing equipment; bookkeepers will use computerized, financial spread sheets; clerical workers in purchasing and inventory will apply their skills to automated and computerized record systems; mechanics will use diagnostic equipment employing mini-computers; and telephone operators will rely on computerized directories. But will the use of these new technologies require workers with more sophisticated skills?

To answer this question, it is necessary to examine how technology is applied in the workplace. The application of technology is part of a more fundamental process that has characterized production historically--the process of dividing work tasks into simplified operations that require few skills to perform. Through this process production tasks are fragmented into repetitive and routinized activities for which unskilled and low paid workers can be employed. This movement toward a minute division of labor was first advocated by Adam Smith in The Wealth of Nations and later refined by Charles Babbage:

> Babbage's principle is fundamental to the evolution of the division of labor...it gives expression not to a technical aspect of the division of labor, but to its social aspect. Insofar as the labor process may be dissociated, it may be separated into elements some of which are simpler than others and each of which is simpler than the whole. Translated into

> market terms, this means that the labor power capable of performing the process may be purchased more cheaply as dissociated elements than as a capacity integrated in a single worker. Applied first to the handicrafts and then to the mechanical crafts, Babbage's principle eventually becomes the underlying force governing all forms of work ...no matter in what setting or at what hierarchical level (Braverman 1974, pp. 81-82).

Technology aids this process. The division of work tasks into component parts is often accompanied by the mechanization of some of those tasks. For example, the assembly line adopted by Henry Ford early in this century, although first controlled by nonmechanical methods, was soon mechanized (Gartman 1979, p. 200). As technology advances, an increasing number of work tasks can be mechanized. Advances in micro-electronics, in particular, threaten to further fragment work tasks and contribute to the "deskilling" of jobs (Cooley 1983).

The process of fragmentation not only allows employers to lower their costs, but to better control the production process. The organization of work in the United States has evolved from many small, local units into a much smaller number of large, hierarchical, national and international organizations. This transformation has been accompanied by more sophisticated methods of control (Marglin 1974; Edwards 1979).

Technology also aids efforts to control the workplace:

> Machinery offers to management the opportunity to do by wholly mechanized means that which it had previously attempted to do by organization and disciplinary means. The fact that many machines may be paced and controlled according to centralized decisions, and that these controls may thus be in the hands of management, removed from the site of production to the office--these technical possibilities are of just as great interest to management as the fact that the machine multiplies the productivity of labor (Braverman 1974, p. 195).

In the case of the automotive assembly line, for example, mechanization not only reduced labor costs but allowed management to more easily control the pace of production (Gartman 1979).

It is often asserted that while machines will increasingly perform tasks previously performed by workers, generally the machines will perform the most tedious and least skilled tasks. That is, the most desirable and challenging tasks will continue to be performed by workers. Further, as automation becomes more widespread, with more and more workers using complex, sophisticated machines, workers will need increasingly complex skills to work with them.

James Bright, a professor at the Harvard Business School, investigated similar claims more than 20 years ago. He examined the effects of automation on job skill requirements in a variety of U.S. manufacturing firms. The general assumption, which was as common then as today, was that increasing levels of automation required increasing skills by operators and other production workers (Figure 1). Bright observed, however, that the skill requirements of jobs first increased and then decreased sharply as the degree of mechanization increased:

> ...there was more evidence that automation has reduced the skill requirements of the operating work force, and occasionally of the entire factory force including the maintenance organization...automated machinery tends to require less operator skill after certain levels of mechanization are achieved. It seems that the average worker will master different jobs more quickly and easily in the use of highly automatic machinery. Many so-called key skilled jobs, currently requiring long experience and training, will be reduced to easily learned, machine-tending jobs (Bright 1958, pp. 86-87).

Evidence for the United States as a whole supports Bright's conclusions: aggregate skill requirements of jobs in the U.S. economy have changed very little over the last two decades despite widespread automation in many industries (Rumberger 1981).

Case studies that have documented the application of more recent technologies in a broad variety of work settings confirm this tendency (Zimbalist 1979a). For example, many of the jobs in the printing industry, such as typesetting, press operating, and photoengraving, historically have required highly complex craft skills (Zimbalist 1979b). A series of technological advances over the last 30 years has enabled many of these operations to be performed by machines. The introduction of teletypesetting machines in the 1950s took over many manual typesetting operations. Then the introduction of computer-aided phototypesetting in the 1960s took over the tasks of word hyphenation and line justification. Finally the introduction of video display terminals removed the tasks of composing from the press floor altogether (Zimbalist 1979b, pp. 107-109). These advances reduced sharply the skill levels of workers who remained in the newspaper composing room.

The computer industry itself, the heart of the high technology revolution, provides another case. Early computers were not only large and expensive by today's standards, but they required programmers and operators with fairly complex skills to use them (Kraft 1977; Greenbaum 1979). But as the technology changed, so did the tasks and the skills involved in their operation. Computer programming was soon divided into the more creative, skilled tasks--performed by computer systems analysts--and the more tedious, routine tasks--performed by computer programers and coders. Programming itself became easier as computer languages evolved from high-level machine languages to packaged programs to more "user-friendly", menu-prompted packages (Kraft 1977).

Advances made in computer software have meant that workers can use computers in a wide variety of work settings without any knowledge of computer languages. The new generation of office computers, for example, are specifically designed so that "no special computer skills are needed to operate" them (Giuliano 1982, p. 149). Moreover, office computers perform many of the tasks formerly done by secretaries, actually reducing the requisite skills of office work (Glenn and Feldberg 1979). Word processors can correct typing errors automatically by use of electronic dictionaries, so letter-perfect typing and strong spelling skills are no longer required. In addition, supervisors can monitor each operator's output and compare productivity among workers instantaneously (Glenn and Feldberg 1979; Arnold, Birke, and Faulkner 1981).

Computers and other products of the micro-electronics revolution are transforming work in virtually all sectors of the economy, from agriculture to transportation to engineering design (Scientific American 1982). The future suggests that this transformation will become even more widespread and that technologies will become increasingly sophisticated. Machines will be able to perform more complex, mental tasks as more advanced software is developed. But the use of such sophisticated equipment will not necessarily require workers with more sophisticated skills. In fact, past technological advances suggest the opposite is often the case. The automobile of today is far more sophisticated than its predecessor of fifty years ago. Yet, today's car is far easier to drive. Computers are far more sophisticated today than they were 10 or 20 years ago. But programming and using computers are considerably less demanding today, and many computer-related jobs require virtually no knowledge of computers.

A related concern is that entire classes of skilled workers will disappear or will be severely reduced in numbers as their jobs are replaced by robots or computer software. For example, robots could replace up to 3 million operative jobs in the next 20 years and potentially eliminate all 8 million operative positions—currently 8 percent of the workforce—by the year 2025 (Ayres and Miller 1982, p. 42). The widespread use of computer-aided design (CAD) may virtually eliminate the occupation of drafter in the not-too-distant future, a potential loss of 300,000 skilled positions (Gunn 1982). The potential of high technology to displace jobs more generally is ominous (Leontief 1982).

It is clear that applications of high technology can be used to enhance the quality of working life and the utilization of worker skills, or to reduce them (Walton 1982). The outcome will depend on how the technologies are applied and how employers use them. Past applications of technology in the workplace as well as present evidence suggest that future technologies will further simplify and routinize work tasks and reduce opportunities for worker individuality and judgement. Moreover, the displacement in jobs and the downgrading of skill requirements for most of the new positions will undermine employment generally, and especially the employment of skilled workers.

Educational Implications

Given the widely, advertised view that high technology will dominate the demand for new workers and raise skill requirements of jobs, the usual prescription is that there must be a vast transformation of the educational system. It is assumed that rising skill levels for employment will require more training in mathematics, computer science, and technical applications for the labor force as a whole as well as an increasing number of workers with specialized training in these fields. Consequently, schools must adapt to these new responsibilities through major upgrading of mathematics and science curricula as well as teacher preparation. Schools also need to establish specialized courses of study in computer applications and programming to provide vocational training for high school and community college students.

We have asserted, however, that while some jobs will require these skills, the vast majority will not. Indeed, one of the major purposes and effects of high technology is to simplify or reduce the skill requirements for performing a particular work task. With the exception of a relatively small number of highly specialized positions for designing and implementing high technology applications, most jobs will not require higher skill levels. Industrial shifts and technological change may require different skills, but the preponderance of persons affected by such shifts will not need more mathematics or computer science. And, for significant numbers of jobs, the skill requirements that will have to be met will be less-demanding.

Based upon these assessments, what educational policies are implied?

First, the general educational requirements for creating good citizens and productive workers are not likely to be altered significantly by high technology. Everyone should acquire strong analytic, expressive, communicative, and computational skills as well as extensive knowledge of political, economic, social, and cultural institutions. These aptitudes and knowledge are required for understanding daily experiences and for ensuring access to social opportunities. To the degree that the present schools fall short of providing these results, they should be sought for their own sake rather than because of the claim that they are required for a high technology future.

Second, since we cannot predict in any precise sense which jobs will be available to particular persons, which jobs they will select from among those available, and what the characteristics of jobs will be over a forty year working life, it is best to provide students with a strong general education and an ability to adapt to a changing work environment. Such adaptation requires a sufficient store of information about culture, language, society and technology as well as the ability to apply that information and acquire new knowledge. Accordingly, general academic and vocational preparation should be stressed, as opposed to specific training, especially for young students.

Specific job skills can best be learned on the job, if a worker's general background is sufficient (Thurow 1975). Recent surveys of both U.S. and British employers indicate that they seek new employees with a sound education and good work habits rather than narrow vocational skills (Maguire and Ashton 1981; Wilms 1983).

Third, if changes in work requirements arise abruptly and change occurs at a faster rate than previously, the educational system may need to respond more quickly and efficiently to training needs. It may require better ties with industry and should not exclude the possibility of more industry-based training activities. It should also be tied to a system of recurrent education, since workers will no longer be able to acquire a set of job skills at the beginning of their careers that will be useful over their entire work lives (Levin and Schutze 1983; Mushkin 1974).

In summary, the educational implications of high technology are that a solid basic education rather than narrow vocational preparation will become more important in the future. This will require elementary and secondary schools to strengthen virtually all their instructional offerings that require analytical and communicative skills.

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Table 1

Employment and Employment Growth in the Fastest Growing Occupations: 1978-90

Occupations	Employment (thousands)		Employment Growth 1978-90		
				Number of Jobs	
	1978	1990	Percentage Increase	(thousands)	(percent of all occupations)
Fastest relative growth[a]					
1. Data processing machine mechanics	63	156	148	93	0.4
2. Paralegal	28	66	132	38	0.2
3. Computer systems analysts	185	384	108	199	0.9
4. Computer operators	169	317	88	148	0.7
5. Office machine and cash register servicers	49	89	81	40	0.2
Total	494	1012	105	518	2.4
Fastest absolute growth[b]					
1. Janitors and sextons	2585	3257	26	672	3.1
2. Nurses' aides and orderlies	1089	1683	55	594	2.7
3. Sales clerks	2771	3362	21	591	2.7
4. Cashiers	1501	2046	36	545	2.5
5. Waiters/Waitresses	1539	2071	35	532	2.4
Total	9485	12419	31	2934	13.3
Total, all occupations	97610	119590	23	21980	100.0

[a] Based on the percentage increase in the number of jobs created

[b] Based on the number of jobs created

Source: Carey (1981), Table 2

Table 2

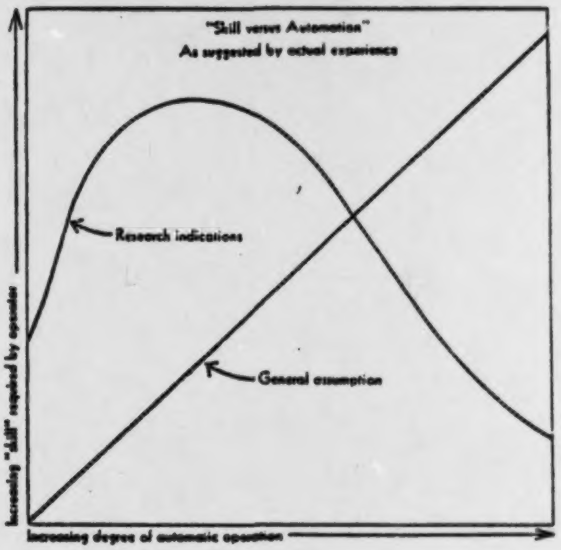
Employment Growth by Major Occupation Group: 1960-90

Major Occupation Group	Employment Growth (percentage distribution) 1960-70 (1)	1970-80 (2)	1978-90 (3)
Professional and technical	30.0	22.3	20.3
Managerial	6.0	22.7	7.7
Sales	5.8	2.6	7.0
Clerical	32.9	21.0	20.0
Crafts	11.2	9.5	12.2
Operatives	7.5	1.8	10.0
Laborers	.7	4.8	4.8
Farm workers	-14.5	- .2	- 2.6
Service	20.4	15.5	20.7
Total	100.0	100.0	100.0

Sources: (1)-(2) Rumberger (1983), Table 2; (3) Carey (1981), Table 2.

Figure 1

The Relationship Between Increasing Levels of Automation and Job Skill Requirements



Source: Bright (1966), p. II-209.

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FORECASTING THE IMPACT OF NEW TECHNOLOGIES ON THE FUTURE JOB MARKET

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and
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February 1984

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INSTITUTE FOR RESEARCH ON EDUCATIONAL FINANCE AND GOVERNANCE

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Abstract

This paper examines recent occupational projections in order to determine how new technologies will affect future job growth in the United States. The first part of the paper reviews the methodologies used to derive occupational projections, focusing on how adjustments for technological change are incorporated into the forecasts. The second part of the paper reviews the most recent projections produced by the U.S. Bureau of Labor Statistics and compares them with projections produced by other organizations. The results reveal that neither high-technology industries nor high-technology occupations will supply many new jobs over the next decade. Instead, future job growth will favor service and clerical jobs that require little or no postsecondary schooling and that pay below-average wages.

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New technologies are having a widespread and visible impact on work in the office, the factory, and even the farm. More and more workers, from managers to construction workers, are using computers in their jobs. Employment in engineering, computer specialties, and other technical fields is increasing, while employment in some traditional craft fields is declining. New job skills are emerging and some old ones are becoming obsolete.

This transformation is part of a continuing process of technological change that has been going on throughout the nation's history. Past technical developments reduced the labor requirements of farming and transformed work in the factory. Today's rapid developments in micro-electronics, biological sciences, and other "high tech" areas are transforming work in virtually all sectors of the economy.

This transformation promises renewed economic prosperity for the nation, but, at the same time, it may profoundly alter the nature of work in our society. It may stimulate economic growth and competition in the world marketplace, but it will displace thousands of workers and could sustain high unemployment for many years. It may provide increased job opportunities for engineers, computer operators, and robot technicians, but it also promises to generate an even greater number of low-level, service jobs such as those of janitors, cashiers, clericals, and food service workers. And while many more workers will be using computers, automated office equipment, and other sophisticated technical devices in their jobs, the increased use of technology may actually reduce the skills and discretion required to perform many jobs.

The promises and fears associated with technological change are not new. The Luddites in eighteenth century England smashed new loom machines because they feared the loss of their jobs. High unemployment during the Great Depression generated similar fears of job loss from technological development.

During the early 1960s the debate over the social and economic consequences of technological change once again became widespread. Unions were particularly vocal over this issue as more and more factories became automated and the national unemployment rate reached the fearful level of

6.8 percent. This concern prompted President Johnson to appoint a National Commission on Technology, Automation, and Economic Progress (1966). But as the commission debated the issue, the unemployment rate fell below 5 percent. The commission, as well as most of the studies that were done at this time, concluded that the fear of widespread and continued high unemployment was unfounded. Technological change affected some workers, industries, and areas of the country, but sustained economic growth would more than offset these losses and assure enough jobs for all workers somewhere in the economy.

Today the concerns over technological change have resurfaced. High unemployment and the rapid application of new technologies have raised the same questions that were raised by previous generations. Are these concerns largely unfounded as the previous concerns appeared to be?

Many people believe that high tech will provide substantial new job opportunities in occupations and industries associated with these new technologies, and that other workers will be using computers and other high-tech devices in their existing jobs. They contend that the sophisticated nature of these new technologies requires increased education and training to prepare for these opportunities. And finally they suggest that, while technology may eliminate some jobs, the sustained economic growth it will foster will provide plenty of new jobs to offset these losses.

Yet these beliefs may be based on a number of misconceptions about high technology. First, there is a widespread confusion between high-tech industries and high-tech occupations. High-tech industries—those industries engaged in the manufacture of computers, electronic components, and other technical devices—employ 15 percent or less of the work force in the United States. Moreover, less than a quarter of the jobs in these industries require substantial knowledge of technology, what may be called high-tech occupations. Most of the jobs in high-tech industries are in production and office areas that pay below-average wages. Neither high-tech occupations nor high-tech industries currently employ or are likely to employ more than a fraction of the work force in this country.

A second common misconception is that rapid growth rates for computer specialists, engineers, and other high-tech occupations translate into large increases in employment in these fields. In reality, most of these occupations employ relatively few workers compared to many traditional clerical and service fields. So even if employment in high-tech occupations expands much more rapidly than employment in other occupations, only a small fraction of the new jobs will be in these areas.

A final misconception is that future economic growth, spurred by high technology, will provide more than enough jobs to offset those displaced by machines. After all, the reasoning goes, past job losses in agriculture and manufacturing due to technological displacement were more than made up for by rapid employment growth in service industries. Why should the future be any different?

Yet history may tell us very little about the future. New technologies differ significantly from those of the past and therefore may have different impacts. Past technologies created new machines that greatly reduced the physical demands of work in agriculture, manufacturing, and construction. Future technologies, based on sweeping developments in micro-electronics, could greatly reduce the mental demands of work in virtually all sectors of the economy. The impact of these technologies is likely to be more widespread than that of past technologies because their cost has declined so sharply relative to their capability and relative to the costs of labor. The sharp reduction in price and the increased capacity of the computer provides the most vivid illustration of these developments.

Equally important, the economic context has changed considerably from the past. Unprecedented deficit spending levels and high interest rates have dampened the chances for sustained economic growth during this decade. Perhaps the biggest economic change, however, concerns the world marketplace. Technological advances in communications, transportation, and automated production have facilitated the movement of production facilities to all parts of the the world and created a worldwide marketplace for goods, services, and, most recently, labor. Japan, Europe, and an increasing number of Asian and Latin American countries now produce products that compete with those from the U.S., even in state-of-the-art fields such as micro-electronics. The U.S. dominance of the world marketplace has now ended. U.S. workers now fear for their jobs, not just from other areas of the country, but from other areas of the world.

The unknown course of technical and economic developments makes it exceedingly difficult to anticipate their impact on future employment. Yet there is an important need to do so. If the educational system is to prepare tomorrow's workers, it must have some idea of what the future job market will look like. If government policy-makers wish to address potential disruptions from job displacement by providing effective retraining programs, they need to know which occupations will decline and which ones will emerge or grow. And if communities want to plan for their economic future, they need an indication of what to expect in terms of the structure of the job market.

While it is impossible to know precisely what the future job market will look like, it is possible to make useful projections on the pattern of jobs that are likely to be available. In a recent paper (Levin and Rumberger 1983) we examined projections for the job market in the year 1990 from the U.S. Bureau of Labor Statistics (BLS). We found that, although the percentage growth rate of occupational employment in such high-technology fields as engineering and computer programming was higher than the overall growth rate of jobs, far more jobs would be created in low-skilled clerical and service occupations than in high technology ones.

This report has been produced as part of a long-range study of high technology and labor markets. In this paper we will review the most recent employment projections by the BLS, for the year 1995, and compare them with those made by other organizations. We will also review the methodologies used in making the various projections. In subsequent papers we will examine the impact of technology on the number of jobs available in the future and on the skill requirements of future jobs.

Forecasting the Future Job Market

Before presenting and analyzing some recent forecasts of the future job market, it is important to address two questions that pertain to all such forecasts. First, how should the accuracy of occupational projections be evaluated? Second, what are the appropriate techniques for deriving projections?

Accuracy

There are two criteria for judging the accuracy of particular occupational projections. One criterion is whether they provide better estimates for the use at hand than alternative methods, such as intuition, guessing, or simple extrapolations of existing trends. A second criterion is whether they meet the overall needs for the specific uses to which they are put. That is, even if they are the best projections among alternatives, there is a question of whether the errors are likely to be small enough that one can answer with reasonable confidence the questions at hand.

The answer to these questions depends upon the methodology underlying the projections and upon the uses to which the findings are applied. In general, sophisticated methodologies, such as those of the BLS, provide better estimates than extrapolation of existing trends or other simple techniques. In fact, as we will show, it is possible to evaluate systematically any biases in past BLS projections. The BLS has done this regularly as a basis for improving forecasting methods to reduce those sources of bias (Christy and Horowitz 1979; Carey 1980; Carey and Kasunic 1982). Other researchers have evaluated whether the costs of more rigorous approaches to forecasting are justified in terms of better policy decisions (Fishkind and Roberts 1978).

With respect to the uses of the data, it is easier to identify aggregate employment trends for broad categories of occupations--such as those jobs requiring high levels of skills versus those requiring low levels, or service occupations versus manufacturing occupations--than it is to estimate employment growth in a particular occupational area, such as fiber optics technician. The reason is that overall shifts in technology and products are more likely to create changes within the same occupational level. For example, what if there is a profound shift from shopping in stores to shopping by computer that is not anticipated by the forecasters? In that case, the projections will probably overstate the growth in jobs for salesclerks and understate the growth in jobs for clericals. Since both jobs require only high school education, there is little or no bias in the projections for occupations requiring high school graduates, even though the composition of occupations within that aggregate is altered.

Thus occupational projections are better able to reflect aggregate trends than the absolute numbers of individual positions. If one wishes to know which occupations are likely to decline and which ones to grow as well as whether the growth or decline will be at a slow or rapid rate, the projections are likely to be more useful than if one needs accurate projections of the numbers of jobs that will emerge for narrow occupational classifications. In the analysis that follows, we will use forecasts for assessing trends and for comparing growth in occupations that require postsecondary schooling with those that do not.

Techniques

A number of techniques can be used to make occupational forecasts. Some techniques are simple and inexpensive; others are quite complex, involving a number of steps, and are therefore quite costly. One simple technique is simply to ask employers to identify their future employment needs. This technique has been used to project future needs for engineering and computer personnel in the electronics industries (Hubbard 1981). Another simple technique is to extrapolate present employment needs into the future based on past trends. For example, projected needs for scientific personnel could be derived from information on present employment in these areas and expected growth in the industries where such workers are employed.

More sophisticated techniques attempt to account for a larger number of factors that might influence future employment opportunities. Most of the more comprehensive approaches are based upon elaborations of the following relationship (Fechter 1975, p. 11):

Employment = Output x Labor/Output x Employment/Labor.

This relationship simply says that the future employment requirements in any particular occupation can be estimated from projections of future output, the total labor required for each unit of future output, and the number of persons employed in that occupation per unit of total labor. Although this basic framework is straightforward, its application requires a complex evaluation of the expected output, employment, and occupational requirements for every industry of the economy, as well as adjustments for changes in technology, productivity, and other factors.

This technique does not consider how changes in relative prices among categories of labor and capital might result in substitution between these two factors of production. The effects of substitution can be captured through adjustments in the labor/output and occupation/labor ratios, but these adjustments are normally made in an ad hoc fashion, not through an explicit price model.

This approach projects the total number of jobs that will be available in the future, not the number of job openings. The number of job openings due to death and retirement is two to three times greater than the number of openings due to employment growth (U.S. Bureau of Labor Statistics 1982, p. 9). An even greater number of openings arise from turnover. Replacement needs are generally higher in low-paying jobs, since they experience more turnover than higher-paying ones. Thus, employment projections will understate future job openings for all jobs, but more so for the lower paying ones requiring the least education.

The more elaborate the forecasting technique, the more refined will be the method for estimating each of the variables in the relation set out above. For example, economic growth for the economy, the composition of output among goods and services, changes in production techniques and other technological impacts will affect each of the determinants. The most comprehensive techniques attempt to take account of all of these concerns, while the simple ones do not.

All projection techniques, no matter how sophisticated, require some assumptions about the future economy and labor market. The assumptions attempt to anticipate what the future will look like. Some are simply based on extrapolations of past trends. For example, if labor productivity (output/labor) increased at an average annual rate of 3 percent over the last 20 years, then this same rate of growth might be assumed to continue into the future. More sophisticated techniques make assumptions about future conditions on the basis of systematic adjustments, rather than relying on simple extrapolations. Yet even the most sophisticated techniques cannot anticipate some of the factors that might influence future job growth, such as war and economic recessions. All projections therefore assume that economic and political conditions will be relatively stable over the period of the forecast.

One way of dealing with future uncertainties is to construct a series of alternative assumptions about future conditions. These alternative scenarios can then be used to construct alternative forecasts. For instance, one forecast might be based on assumptions of faster economic and productivity growth rates and another based on assumptions of more modest growth rates.

Occupational forecasts that try to account for the impact of technological change are particularly difficult to make. Even if forecasters limit their analysis to evaluating the impact of technologies that exist at the time the forecasts are made, it is still extremely difficult to determine the speed and the particular manner in which technologies will affect the future job market. This problem is even more difficult today because of the rate at which advances in micro-electronics are taking place and the potential use of technologies based on these advances throughout the economy.

Most forecasters acknowledge, for example, that robots will be used more widely in our future economy. But it is much more difficult to project future employment needs for robot technicians because no one knows just how fast and how widely robots will be introduced into the economy. Moreover, as robot technologies become more fully automated, labor requirements to build robots will likely decline. Simple projection techniques based on anticipated needs or simple extrapolations make little or no attempt to account explicitly for the diffusion of technology throughout the economy and, therefore, provide limited information on future job requirements related to new technologies.

The ability to accurately project the impact of technology on the future job market depends on the time horizon over which the projections are made. Short-term projections, covering a period of several years, are less likely to deviate from current trends, although they are still subject to the effects of unanticipated events such as economic downturns. Long-term projections are more difficult to make, especially in areas related to new technologies. For this reason, most long-term projections are limited to periods of 10 or 15 years. The BLS revises its projections every two years to account for these changes and to provide feedback to the forecasting process on improving adjustments for technological change and other factors (Andreassen, Saunders, and Su 1983, pp. 12-13).

While all comprehensive forecasts of occupational growth or decline use the same general techniques, differences in particular techniques and in assumptions about the future economy can lead to different results. A review of the particular techniques used by the BLS and other agencies illustrates these differences.

BLS Projections

Since the 1940s the BLS has produced the most widely used and comprehensive occupational projections in the United States. Projections are made for a 10 to 15 year period, targeted on the beginning or middle of the next decade. The BLS has developed an elaborate methodology and provides forecasts for the entire economy rather than limiting its efforts to particular occupations. It has systematically evaluated the accuracy of its own projections over time and used these evaluations to improve its methodology. The latest projections, which cover the period from 1982 to 1995, will be examined in detail in the next section of the paper.

The BLS derives its projections from the basic model described above, where occupational requirements are estimated for each industry based on projected output growth, growth in labor productivity, and the occupational composition of each industry. These requirements are then aggregated to produce occupational requirements for the economy as a whole. Over the years this basic methodology has been improved and more accurate data have been collected to improve the relative precision of the projections. For instance, the BLS now uses data on occupational requirements in industry from surveys specifically designed to collect that information, rather than from the decennial census that was used in the past. The BLS now makes several occupational projections based on alternative economic scenarios rather than a single projection.

The methodology that is currently used to make projections includes a number of distinct steps (Oliver 1982, p. 1):

1. Projecting the size of the future labor force;
2. Projecting aggregate economic output with a macro-model;
3. Disaggregating the projected GNP into detailed demand categories;
4. Distributing each demand category into detailed, producing industries;
5. Projecting an I-O (input-output) table to distribute intermediate products among industries;
6. Projecting productivity, hours, and employment for each detailed industry;
7. Projecting an industry-occupation matrix for each industry to derive occupational employment by industry;
8. Aggregating occupational employment across industries to derive total occupational employment within the economy.

In the current estimates, three sets of assumptions regarding economic growth and inflation are used in step 2, yielding three sets of occupational forecasts.

There are two places in this process that the BLS attempts to account for the impact of technological change. One is in step 5 where adjustments are made for anticipated changes in the input requirements of each industry. For instance, the increased use of plastics and the decreased use of steel in producing automobiles would affect the demand for the products from these two industries as well as the employment generated in them. The second is in step 7 where adjustments are made for anticipated changes in the occupational composition of an industry due to the use of new technologies. In the automobile industry, for example, the increased use of robots would lower the labor requirements for operatives, who are replaced by the robots, and raise the requirements for robot technicians.

Evaluations of past projections reveal that the BLS has been more successful in identifying how emerging technologies are likely to affect future job growth than in ascertaining the speed with which such effects are likely to come about. In the 1975 projections, for instance, the BLS correctly identified the laborsaving effects of technologies related to the employment of knitters, weavers, telephone operators, and several railroad occupations (Carey 1980, p. 19). But it did not anticipate the rate at which these new technologies would be adopted and the resulting employment declines for telephone operators, railroad engineers, and brake and switch operators. And while employment declines for weavers, knitters, and locomotive engineers were anticipated, they were understated. An evaluation of the 1980 BLS projections yields a similar conclusion (Carey and Kasunic 1983, p. 24): "the BLS has been more successful in identifying employment growth than employment declines and where they have correctly identified employment declines, they have often underestimated the rate of decrease."

At the other extreme, the BLS has tended to overstate the employment growth in some technical fields, especially engineering (Goldstein 1983, p. 56). In general it appears that past projections have overstated the growth of technical occupations and understated the decline of certain traditional jobs.

Overall, however, the BLS projections have been fairly accurate. Comparisons between actual employment levels and projected employment levels for detailed occupations reveal an average absolute error of 21 percent for the 1975 projections and 22 percent in the 1980 projections.

When weighted by the level of employment in each occupation, the average absolute error declines to 14 percent in both years (Carey 1980, p. 14; Carey and Kasunic 1982, p. 23). In a recent evaluation of the BLS projections, Goldstein (1983, p. 55) found that 80 percent of BLS forecasts for detailed occupations in 1975 were within a 10 percent range of actual employment levels for that year and 60 percent of the 1980 forecasts fell within that range. The poorer performance in the more recent forecasts may indicate an increasing difficulty in anticipating the future impact of technological change as well as the sharp changes in the fortunes of the economy. The estimates for 1995 have attempted to accommodate more fully adjustments for a range of assumptions that might reduce such errors.

NSF Projections

As part of its concern with scientific and technological activities in the U.S., the National Science Foundation (NSF) provides information on the market for scientific and technical personnel. This information includes projections of the supply of and requirements for scientists and engineers. In the 1950s and 1960s, the BLS derived special projections of scientific and technical jobs for the NSF. Beginning in the late 1960s, NSF began to develop its own projections for doctoral-level science and engineering personnel. Earlier projections were made for the years 1980 and 1985, based on data for the years 1968, 1969, and 1975. The most recent projections for science and engineering doctorates were made for the years 1982 and 1987 (NSF 1979). In 1983, NSF published projections for 1987 that include all science, engineering, and technician personnel (NSF 1983).

The NSF extrapolated trends in undergraduate enrollments to project academic requirements for science and engineering personnel and trends in research and development funds to project industry requirements for these personnel (NSF 1979, pp. 29-30). These rather simple techniques have been quite satisfactory in estimating requirements for these particular occupational areas, especially when employment is concentrated in only a few sectors of the economy. Recent results compare favorably with those developed by the BLS (NSF 1979, p. 32).

In the latest projections, NSF used a much more sophisticated, multi-step model similar to the one used by the BLS. The basic model, referred to as the Defense Interindustry Forecasting System (DIFS), is a commercial version of a model developed by the Department of Defense and Data Resources, Inc. to analyze the economic impact of defense spending on the U.S. economy (Dale 1983, p. 161). Some steps of the model--such as the macro-economic forecasts and the interindustry relationships--differ from those developed by the BLS, while other components--specifically, the occupational staffing patterns within industries--are based on the BLS model.

As with the BLS model, there are two places where the impact of technological change can be assessed: in the interindustry relationships, and in the occupational staffing patterns. Since the latter component comes from the BLS, only the former component is likely to yield any different projections with respect to technological change. But since the model is not really designed to address this factor, it is unlikely to provide any better assessment of the impact than can be derived from the BLS projections. The advantage of this model is that it assesses the requirements for scientific and technical personnel based on alternative assumptions about the growth of military spending as well as on alternative assumptions about economic growth.

IEA Projections

The Institute for Economic Analysis (IEA) at New York University has recently completed an economy-wide projection of occupational employment for the years 1990 and 2000 (Leontief and Duchin 1983). These projections, based on the pioneering work of economist Wassily Leontief, demonstrate an alternative way of trying to assess the future impact of technological change on employment.

The basic model used to derive these projections is similar in some respects to the model used by the BLS. In fact, the basic macro-economic projections and much of the data come from the BLS and other government agencies. But the IEA model differs from the BLS in several important respects. First, it models the relationships between industries in a dynamic fashion, estimating changes in those relationships on a yearly basis instead of using a single adjustment for the entire projection period as done by the BLS. The most recent BLS estimates, for example, are based on 1972 interindustry relationships that are then adjusted for the year 1995. Second, the IEA accounts for changes in the capital requirements--both replacement capital and expansion capital--related to several new technologies, such as computers, robots, and office automation equipment. Third, the IEA model uses projected labor requirements for this new capital to derive occupational employment rather than using industry staffing patterns.

A specific example can illustrate the application of the IEA model. One impact of the increased use of computers in production is through the use of computer-aided design (CAD) equipment, which reduces the requirements for drafters. Two of the three scenarios used in the IEA projections assume increased rates of diffusion of this technology and hence different rates at which drafters will be displaced. One scenario assumes that the requirements for drafters will be greatly reduced by the year 2000, while the other scenario assumes that all drafters will be eliminated (Leontiff and Duchin 1983, p. 4.19). Similar techniques are used to project employment growth in industries producing new technologies, such as computers, robots, and office automation equipment, and to project employment declines in industries where the technologies are used.

The IEA model makes an explicit attempt to account for the impact of technological change on employment. While the BLS does attempt to account for that impact, the adjustments to interindustry relationships and occupational staffing patterns are generally ad hoc and the assumptions underlying them are not published systematically. The IEA model also incorporates personal judgements about the probable impact of technology, but many of the assumptions and information underlying those judgements are described explicitly.

In order to account for different rates of diffusion of new technologies, the IEA projections contain three different scenarios. One assumes no further technological changes after 1980, only increased demand based on the relationships that existed in that year. The other two scenarios assume increased diffusion of technical devices throughout most sectors of the economy and changing labor requirements associated with their use.

The IEA model is the first economy-wide model specifically designed to forecast the impact of technological change on future employment. It also is the first to provide alternative scenarios based on different assumptions about the rate of diffusion of technology. Despite these improvements, the IEA model still does not address other factors likely to affect future employment. It does not address technological advances that could affect production and labor requirements in the agricultural, telecommunications, and publishing fields (Leontief and Duchin 1983, p. 1.28). Nor does it examine possible changes in foreign trade and production that could also produce significant changes in domestic employment (Bluestone and Harrison 1982, pp. 42-46). The resulting estimates may be more dynamic and realistic than those produced by the BLS, but they still may not go far enough in assessing how technological change throughout the economy may affect the future level and composition of employment in this country.

Other Projections

The Department of Defense has projected occupational requirements in a number of areas based on anticipated defense spending. These projections are based on the same model as the recent NSF projections described above. In addition to occupational areas, the projections examine demands on particular industries (Dale 1983).

Other projections concentrate on the future needs for specific occupations. The National Center for Education Statistics (1982) provides projected requirements for teachers based on expected trends in the school-age population. The American Electronics Association recently projected needs for engineers and computer specialists in the electronics industry (Hubbard 1981). These projections, while useful to individuals and organizations concerned with the future needs in these fields, provide little information about the overall impact of technological change in the future economy.

The Future Job Market

Although employment in particular occupations may change rapidily in the future, recent projections indicate that employment in major industrial and occupational categories is likely to follow past trends. Over the nation's history, the economy has been dominated by several key industries. Agriculture was the primary economic activity in the nation's first one hundred years. Even as late as 1900, 4 out of 10 workers in the U.S. were employed in agriculture (Table 1). But by that time the majority of workers were employed in two other areas, goods-producing industries--mining, construction, and manufacturing--and services-producing industries--transportation, public utilities, trade, finance, insurance, real estate, services, and government. Agricultural employment has declined steadily and quickly since the turn of the century. By 1980 only 3 percent of the work force was employed in this sector. Employment in goods-producing industries has remained fairly constant during this period, while employment in service industries has grown tremendously--from 31 percent of the workforce in 1900 to 69 percent of the work force in 1980.

These changes have shaped the composition of jobs in the economy. Employment in farming occupations declined as the farming industry became a less significant employer (Table 2). The constant share of employment in goods-producing industries has maintained jobs related to those industries, particularly craft and operative occupations. The growth of service industries has spurred employment in occupations related to these areas, particularly professional and technical, clerical, and other lower-level service jobs such as custodians, waiters, and cashiers. To a lesser degree, shifts in the composition of occupations within industries, such as the increasing proportion of clerical and managerial occupations within manufacturing firms, have also altered the composition of employment within the economy.

Employment projections for 1995 indicate that these past trends will continue. Both the long-term trend of declining employment in agriculture and the more recent trend of declining employment in manufacturing will continue in the future (Table 1). Employment in service industries will continue to increase. Employment in other sectors will change little or not at all. Employment within major occupation groups will also change very little. The proportion of the work force employed in professional and technical, sales, and service jobs will increase slightly, while employment in managerial, craft, and operative areas will decline slightly. The increased use of new technologies will do little to alter the composition of employment among major industrial and occupational categories.

Yet more dramatic shifts in employment will take place in detailed industrial and occupational categories. How will technology influence employment growth within particular occupations and industries? The BLS and other recent projections can help answer such a question.

Before proceeding, it is important to emphasize the difference between high-technology industries and high-technology occupations. The growth of high-technology will increase employment in those industries where high-technology products--such as electronic components and computers--are manufactured. It will also spur employment growth in those occupations related to the design, development, manufacture of such equipment as well as in occupations where the equipment is used. We will use the BLS projections to evaluate the employment impact of high technology on both industrial and occupational employment. But in order to assess education and training requirements in the future job market, we focus primarily on occupational projections.

BLS Projections

In the latest projections, the BLS has not only estimated employment growth for all occupations and industries in the economy, but also employment growth within both high-tech industries and high-tech occupations. The BLS defines three groups of high-technology industries (Riche, Hecker, and Burgan 1983, Table 1). The first group consists of industries in which the proportion of technology-oriented workers is at least one and a half times the average for all industries. This standard identifies 48 high-tech industries. The second group, based on the most restrictive definition, assumes that an industry meets the high technology criterion if its ratio of R & D expenditures to net sales is at least twice the average for all industries. Only six industries meet this criterion: drugs; office, computing, and accounting machines; electronic components and accessories; miscellaneous electrical machinery; aircraft and parts; and guided missiles and space vehicles. The third group consists of industries having a combination of technology-oriented workers greater than the average for manufacturing industries and a ratio of R & D to sales at about the average of all industries. This standard encompasses some 28 industries.

Regardless of the definition, high-technology industries currently employ only a small fraction of the total work force and they will continue to employ a small fraction in the future. Even the largest grouping of high-tech industries employed only 13 percent of the workforce in 1982 and will provide only 17 percent of the new jobs in the period between 1982 and 1995 (Table 3). Employment in these industries is projected to grow only somewhat faster than employment overall (35 versus 28 percent). More restrictive definitions indicate that high-technology industries will provide only 3 to 8 percent of the new jobs in the future economy.

Not only do high-tech industries employ only a fraction of the nation's workers, but many of the jobs they do provide require little or no knowledge of high technology. High-technology industries produce products or services which require large numbers of clericals, secretaries, assemblers, warehouse personnel, and so on. It is the production and distribution of high-technology goods and services that provide the sales revenues and profits, and these functions require far more personnel than the research and development functions.

In the electronic components industry, for example, only about 15 percent of workers were employed in engineering, science, and computer occupations in 1980 (Riche, Hecker, and Burgan 1983, Table 3). The majority were assigned to low-wage assembly work. In 1977 almost two-thirds of the workers in that industry received hourly wages that placed them in the bottom third of the national distribution (Applebaum 1983, p. 10). Even in computer and data processing services—virtually a prototype of a high technology industry--only 26 percent of the jobs were technologically oriented in 1980.

Of course in particular states and regions the concentration of high-technology industries may be higher or lower than the national average. In fact, the distribution of high-technology employment is very uneven around the country. Based on the third grouping, for example, 33 percent of the work force in the San Jose, California area was in high technology industries in 1980 compared to only 3 percent in Detroit (Riche, Hecker, and Burgan 1983, Tables 5 and 7). But even where employment in high-technology industries is high, only a small proportion of the jobs are in high-technology occupations.

The BLS defines high-tech occupations as those jobs requiring an "in-depth knowledge of theories and principles of science, engineering, and mathematics underlying technology" (Riche, Hecker, and Burgan 1983, p. 54). The occupations that meet this definition are engineers, life and physical scientists, mathematical specialists, engineering and science technicians, and computer specialists. This group excludes other occupations, such as computer operators and computer service technicians, where workers use or repair sophisticated technological products, but do not require extensive technical competence to fulfill their duties. The BLS definition does include technicians, jobs which require no more than an Associate Degree from a community college, so the overall definition of a high-technology occupation is not restricted to graduates of four year colleges.

According to the BLS definition, only 3 percent of all employment in 1982 was in high-tech occupations (Table 3). Employment in high-tech jobs is expected to increase by 46 percent between 1982 and 1995, but will still only account for 6 percent of the new jobs in the economy. Even these figures may overstate the need for high-level technical skills in the future job market. Many so-called high-tech jobs have been subject to the same fragmentation of job tasks and "deskilling" that have pervaded other sectors of the economy.

Consider the case of computer programming. Early computer programmers, working in machine languages, had "to be comfortable with abstract logic, mathematics, electrical circuits, and machines, as well as some substantive field, such as aerodynamics or cost accounting" (Kraft 1979, p. 4). But soon programming was divided into several occupations--systems analysts, software designers, and applications programmers--each with different tasks and requisite training. As machines became more powerful, computer software evolved from machine languages, to high-level languages (e.g., FORTRAN), to simpler languages, to software packages that required only following menus. New developments in structured programming have meant that many programmers now perform standard, routine, machine-like tasks that require little in-depth knowledge (Kraft 1979, pp. 10-11). The latest micro-computers can be used without programmers altogether because of more sophisticated "user-friendly" software.

If high tech will provide only a fraction of the future jobs, which jobs will provide the most opportunities in the future economy? A common fallacy is to assume that job categories with the fastest relative or percentage growth rates will offer the most new jobs. According to the BLS projections, however, most new jobs will be found in the older, slower growing occupations where relatively smaller percentage increases amount to very large numbers of jobs. The rapidly growing job categories tend to be in occupations with relatively few people so that large percentage increases amount to relatively few new jobs. It is the absolute expansion of employment within occupations, not occupational growth rates, that will determine the distribution of new opportunities.

To illustrate, the 10 occupations projected to grow most rapidly between 1982 and 1995 are shown in the upper part of Table 4. Many of the fastest growing jobs in the economy are either high-tech jobs, according to the BLS definition, or are directly related to the use of high-tech equipment. Eight of the 10 fastest growing occupations involve the production, use, or repair of computers. Employment in these 10 occupations is expected to increase 76 percent between 1982 and 1995, a rate three times faster than the average growth rate for total employment.

Most of the fastest growing occupations require postsecondary education. Persons working as computer systems analysts, computer programmers, and electrical engineers in 1980 generally had completed at least 4 years of college . Workers employed in 5 additional fast-growing occupations had completed 1 to 3 years of postsecondary schooling. Most of these jobs also pay above-average wages. The average weekly earnings in 1979 of workers in 6 of the 10 fastest-growing occupations were significantly higher than the average weekly earnings for all workers in the economy. Earnings for the 10 fastest-growing occupations together were 26 percent higher than average earnings in 1979.

According to these figures, many of the occupations experiencing the fastest growth will be in fields related to high tech. Most of those jobs have required postsecondary schooling, and most have paid above average wages. Yet these occupations will provide only 1 million new jobs, less than 4 percent of all the new jobs that will become available in the 1982-95 period.

Table 4 also shows the 10 occupations with the fastest absolute growth, those occupations expected to add the most new jobs to the economy. The 10 categories with the fastest absolute growth represent over six million jobs or nearly one-quarter of all new jobs that are expected between 1982 and 1995. The occupations that will provide the greatest number of new jobs are building custodians, cashiers, secretaries, clerks.

The 10 occupations with the fastest absolute growth differ substantially from those with the fastest rate of growth. None are related to high technology. Only two--nurses and teachers--require any postsecondary education. And the earnings of workers in these occupations averaged 30 percent below the average earnings of all workers in the economy in 1979 (Table 4). Thus, even though high technology occupations will grow rapidly, they will contribute relatively few jobs to the American economy relative to the low level service occupations that are expected to grow more slowly. Indeed, of the forty job categories expected to account for half of all new jobs, only about 25 percent of the occupations require a college degree (Silvestri, Lukasiewicz, and Einstein 1983, p. 45).

The apparent paradox between the high relative growth rates of high-tech jobs and their relatively small contribution to the overall job situation can be illustrated using the job category that is expected to grow at the fastest rate--computer service technicians. Although the number of job openings for computer service technicians is expected to almost double between 1982 and 1995, that high growth rate will amount to only about 53,000 new jobs. In contrast, the number of jobs for building custodians is expected to increase by only about 28 percent over that period, but that smaller growth rate is expected to generate almost 800,000 new jobs--about 14 times as many as for computer service technicians.

The message from the BLS figures is clear: not only will high tech provide few job opportunities in the future economy, but most new jobs will require no postsecondary schooling and will pay wages significantly lower than the average. Earlier BLS projections yielded similar conclusions (Levin and Rumberger 1983).

Alternative Scenarios for the Future

The preceding conclusions regarding the impact of high tech on the future job market were based on one set of projections from the BLS. As pointed out earlier, the BLS currently provides three sets of occupational projections based on alternative scenarios regarding expected economic growth rates, productivity increases, and inflation levels. Other agencies, particularly the National Science Foundation (NSF) and the independent Institute for Economic Analysis (IEA), have also recently produced occupational projections based on alternative scenarios. The NSF scenarios regard alternative assumptions about expected economic growth rates and military spending levels, while the IEA scenarios are based on alternative assumptions about the diffusion of technology throughout the economy.

Comparing projections from these three agencies suggests that growth rates for some occupations could differ widely from the rates projected by the BLS. The IEA projections show the greatest differences with the BLS, while the NSF projections, based on some of the BLS data, are closer to the BLS figures.

The BLS and NSF figures estimate that both high economic growth rates and high defense expenditures will increase overall employment as well as employment in particular occupations (Table 5). The NSF projections suggest, for instance, that a combination of high economic growth and high defense spending will increase employment more than 2 percent a year between 1982 and 1987, more than 2 times the employment growth expected from low economic growth and low defense spending. The BLS figures, covering a longer period, show overall employment growth rates falling between the two NSF figures. The IEA projections show a higher employment growth rate than the other two estimates.

The BLS and NSF projections for particular occupations are also quite similar. The biggest discrepancy concerns expected growth rates for drafters. The NSF projections were based on older occupational staffing patterns supplied by the BLS, while the newest BLS projections are based on revised staffing patterns. The current BLS projections show virtually no growth for drafters due primarily to the increased use of CAD equipment.

The IEA projections for some occupations, based on scenarios 2 and 3, differ substantially from the BLS projections. Since the IEA model is explicitly designed to account for the impact of technological change, projections for some occupations show much higher growth rates due to the increased use of technology, while others show much lower growth rates due to displacement by machines. For instance, under the assumption of rapid technological diffusion, the IEA projections suggest that all drafting positions will disappear by the year 2000 (Table 5). The IEA projections also show much lower growth rates for secretaries and bank tellers as word processors and automatic teller machines reduce employment needs in these areas. In contrast, employment for computer programmers is expected to increase more than 10 percent per year over the same period. Yet this projection may be overstated because developments in "user-friendly" software will increasingly allow future computers to be used without programmers.

These different sets of projections--produced by different agencies and based on different models and alternative assumptions--suggest similar trends for the future job market. Occupations related to the increased development, production, and use of new technologies will grow faster than employment overall, while occupations that can be replaced by machines based on these new technologies will grow slower or decline. What differs among these projections is the speed with which such changes will take place. But again recall that even rapid changes in the growth rates of particular occupations may affect only a small number of jobs.

Conclusions

According to the BLS projections, high tech will not dominate the future job market. Neither high-tech industries nor high-tech occupations will supply many new jobs over the next decade. Instead, future job growth will favor service and clerical jobs that require little or no postsecondary schooling and pay below-average wages. Even among the jobs that are generated in high-tech, many are support-level and production jobs that require little or no in-depth knowledge of technology. The skill requirements of others, such as programming, are being lowered through advances in computer hardware and software.

Alternative projections by the BLS and projections from other agencies suggest similar trends but different rates of growth for total employment and employment within particular occupations. The faster that robots, computers, automatic teller machines, and other technical devices spread through the economy, the greater the impact on employment. This means faster growth rates for occupations associated with the production, use, and repair of these devices, and slower or even negative growth rates for occupations replaced by them.

Faster economic growth will generate more jobs in all occupational areas, while increased military spending will generate relatively more jobs for scientific and technical personnel because military contractors employ between one quarter and one half of the workers in these fields (DeGrasse 1983, p. 101). The IEA projections suggest that the growth rates of many occupations will be affected much more by the diffusion of technology than by economic growth or the growth of military spending. But, it must be stressed that the development and rate of adoption of new technologies in themselves depend heavily upon investment, a factor which is driven primarily by economic growth and to a lesser extent by orders for new weapons systems.

Technology will not only affect the kinds of jobs available in the future economy, but it will also affect the total number of jobs available and the skill requirements of all jobs. These other two effects have equally important implications.

Consider the impact on the level of employment. It is quite clear that technology creates new jobs and destroys others. Will the net impact of these changes sustain, increase, or reduce employment levels? At least some evidence suggests that more jobs will be destroyed than created by technological change. A recent study of robotics suggests that robots will eliminate 100,000 to 200,000 jobs by 1990, while creating 32,000 to 64,000 jobs (Hunt and Hunt 1983, pp. x-xi). The increased movement of production jobs, even in high-tech electronics, to overseas locations also threatens the level of domestic employment (Bluestone and Harrison 1982, pp. 42-46). The IEA projections suggest that rapid technological diffusion could eliminate 20 million jobs by the year 2000, 11 percent of all the jobs that would exist in the absence of further technological diffusion (Leontiff and Duchin 1983, Table 1.1).

Technology will also have a widespread affect on the skill requirements of future jobs. It is commonly assumed that as more and more workers use computers and other sophisticated, technical devices in their jobs, they will need computer-programming and other sophisticated skills. Yet a variety of evidence suggests just the opposite: as machines become more sophisticated, with expanded memories, more computational ability, and sensory capabilities, the knowledge required to use the devices declines (Levin and Rumberger 1983).

Technology is already having a widespread impact on work and the economy and promises an even greater influence in the future. It could greatly increase the productivity of the American work force and enable this nation to regain its competitive position in the world marketplace. But it could also eliminate jobs and reduce the skills of others. The challenge we face as a nation is to harness the benefits from technology at the same time that we mitigate its potentially negative impact on work and employment.

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Table 1

Employment by Major Industry Group: 1900 to 1995[a]

(percentage distribution)

Industry Group	1900	1930	1960	1980	1995[b]
Agriculture	41	23	8	3	2
Goods-producing					
Mining	2	3	1	1	1
Construction	4	4	5	5	6
Manufacturing	21	24	28	22	18
Services-producing					
Transportation and utilities	9	9	7	6	5
Wholesale and retail trade	10	15	19	22	22
Finance, insur., and real estate	1	4	5	5	6
Services	7	9	12	19	26
Government	4	8	14	17	14

[a] Distributions based on total civilian employment. Nonagricultural employment calculated from data on employees on nonagricultural payrolls, with self-employed and nonpaid family members distributed proportionally among industries.

[b] Data for 1995 based on moderate-trend projections.

Sources: U.S. Bureau of the Census, *Historical Statistics of the United States*, Part 1 (Washington,D.C.: U.S. Government Printing Office, 1975), Tables D1-10 and D127-141; U.S. Council of Economic Advisors, *Economic Report of the President* (Washington,D.C. U.S. Government Printing Office, 1983), Table B-29; U.S. Department of Labor, *Employment and Training Report of the President* (Washington, D.C.: U.S. Government Printing Office, 1981), Table C-1; Valerie A. Personick, "The Job Outlook Through 1995: Industry Output and Employoment," *Monthly Labor Review* 106 (November 1983), Table 2.

Table 2

Employoment by Major Occupation Group: 1900 to 1995[a]

(percentage distribution)

Occupation Group	1900	1930	1960	1980	1995[b]
Professional and technical	4	7	11	16	17
Managerial	6	7	11	11	10
Clerical	3	9	15	19	19
Sales	5	6	6	6	7
Craft	11	13	13	13	12
Operataive	13	16	18	14	12
Laborer	12	11	6	5	5
Service	9	10	12	13	16
Farm	37	21	8	3	2

[a] Distributions for 1900 and 1930 based on experienced civilian labor force. Distributions for other years based on total employed persons.
[b] Data for 1995 based on moderate-trend projections.

Sources: U.S. Bureau of the Census, Historical Statistics of the United States, Part 1 (Washington,D.C.: U.S. Government Printing Office, 1975), Table D182-232; U.S. Department of Labor, Employment and Training Report of the President (Washington,D.C.: U.S. Government Printing Office, 1979 and 1982), Tables A-16 and A-18; George T. Silvestri, John M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review 106 (November 1983), Table 1.

Table 3

Employment and Employment Growth, by High-Tech Industries and Occupations: 1982 to 1995

Industries Occupations	Employment, 1982 (thousands)	Employment growth, 1982-95[a] (thousands)	(percent)
All industries[b]	91,950	25,795	28.1
High-tech industries[c]			
Group I (48 industries)	12,350	4,263	34.5
Percent of all industries	13.4	16.5	
Group II (6 industries)	2,543	867	34.1
Percent of all industries	2.8	3.4	
Group III (28 industries)	5,691	2,029	35.7
Percent of all industries	6.2	7.9	
All occupations[d]	101,510	24,600	25.2
High-tech occupations[e]	3,287	1,508	45.9
Percent of all occupations	3.2	5.9	

[a] Data for 1995 based on moderate-trend projections.

[b] Employment covers all wage and salary workers

[c] Group I includes industries where the proportion of workers employed in high-tech occupations[e] is at least 1.5 times the average for all industries. Group II includes industries with a ratio of R & D expenditures to net sales at least twice the average for all industries. Group III includes manufacturing industries in which the proportion of workers employed in high-tech occupations[e] is equal or greater than the average for all manufacturing industries; two manufacturing industries that provide technical support to high-tech manufacturing industries are also included.

[d] Employment covers all civilian workers

[e] Engineers, life and physical scientists, mathematical specialists, engineering and science technicians, and computer specialists.

Source: Richard W. Riche, Daniel E. Hecker, and John V. Burgan, "High Technology Today and Tomorrow: A Small Slice of the Employment Pie," Monthly Labor Review 106 (November 1983), Tables 2 and 4.

Table 4

Employment, Employment Growth, Required Education, and Relative Earnings for the Fastest Growing Occupations: 1982 to 1995

	Employment, 1982	Employment growth, 1982-95		Required education[a]	Relative earnings[b]
	(thousands)	(thousands)	(percent)	(years)	(percent)
Fastest relative growth[c]					
Computer service technicians	55	53	97	13-15	129
Legal assistants	45	43	94	13-15	86
Computer systems analysts[d]	254	217	85	16	149
Computer programmers[d]	266	205	77	16	122
Computer operators	211	159	76	12	82
Off. machine repairers	56	39	72	12	106
Physical therapy ass.	33	22	68	12	57
Electrical engineers[d]	320	208	65	16	167
Civil eng. techs.[d]	35	23	64	13-15	121
Per. EDP equip. opers.	49	31	63	13-15	73
TOTAL	1,324	1,000	76	--	126
Fastest absolute growth[e]					
Building custodians	2,828	779	28	<12	69
Cashiers	1,570	744	47	12	49
Secretaries	2,441	719	30	12	67
General clerks, office	2,348	696	30	12	67
Sales clerks	2,916	685	24	12	52
Nurses, professional	1,312	642	49	13-15	90
Waiters and waitresses	1,665	552	34	12	39
Teachers, kind./elem.	1,366	511	37	16	110
Truck drivers	1,604	425	27	12	117
Nurses aides and orders.	1,218	423	35	12	58
TOTAL	19,268	6,186	32	--	70
All occupations	101,510	25,600	25	--	--

[a] The level of education completed by the majority of workers employed in each occupation during the spring of 1980.

[b] The average weekly earnings during 1979 of workers in each occupation relative to the average weekly earnings of all workers.

[c] Based on the greatest percentage increase.

[d] High-tech occupations as defined by the BLS.

[e] Based on the greatest increase in the number of new jobs.

Sources: George T. Silvestri, Johon M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review 106 (November 1983), Table 1; Calculations based on the 1980 Public Use Sample, U.S. Bureau of the Census.

Table 5

Projected Average Annual Growth Rates for Total Employment and Employment in Selected Occupations: 1978 to 2000

Agency: Period Scenario	Total Employment[a]	Selected Occupations				
		Electrical Engineers	Drafters	Computer Programmers	Secretaries[b]	Bank Tellers
BLS: 1982-95						
1. Low growth	1.6	4.0	0.2	4.4	1.5	1.9
2. Moderate growth	1.7	3.9	0.4	4.5	1.6	2.0
3. High growth	1.9	4.1	0.6	4.6	1.8	2.1
NSF: 1982-87						
1. Low growth/low defense	1.0	3.9	1.6	4.3	---	---
2. Low growth/high defense	1.3	4.8	2.2	4.6	---	---
3. High growth/low defense	2.1	4.0	2.6	4.6		
4. High growth/high defense	2.4	5.1	3.3	5.0	---	---
IEA: 1978-2000						
1. No technological diffusion	3.2	3.2	3.4	3.6	3.3	3.2
2. Moderate technological	2.9	3.2	-2.8	10.5	2.0	0.8
3. Rapid technological change	2.6	4.0	-16.8	11.7	0.1	-0.9

[a] Definitions of total employment vary slightly among projections.
[b] Includes secretaries, stenographers, and typists.

Sources: George T. Silvestri, John M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," *Monthly Labor Review* 106 (November 1983), Table 1; National Science Foundation, *Projected Response of the Science, Engineering, and Technician Labor Market to Defense and Nondefense Needs, 1982-87* (Washington,D.C.: U.S. Government Printing Office, 1983), Tables B-1-B-8; Wessily Leontief and Faye Duchin, "The Impacts of Automation on Employment, 1963-2000," Institute for Economic Analysis, New York University, September 1983, Table 11 and unpublished figures supplied by David Howell.

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STATE PLANNING FOR HIGHER EDUCATION AND JOBS IN AN AGE OF HIGH TECHNOLOGY

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Abstract

As states enter an age of high technology, they are confronted with the challenge of ascertaining future job needs and the appropriate educational response to preparing a work force for those jobs. This paper presents an analysis of the implications of high technology in the job market and the challenges to states for both job creation and higher education. It asserts that states should take an active role in setting out both job and educational policies that meet their special needs. Specific suggestions are made for the pursuit of both economic and higher educational policies.

Introduction

Along with the nation as a whole, each of the states is entering an age of high technology. High technologies generally refer to the development and use of computers, lasers, communications technologies, information technologies, robotics, and bio-engineering technologies in the economy. Since these technologies are so closely associated with research and development activities, they are often thought to be heavily dependent upon workers with advanced education and training. Indeed, the media are warning that as we move towards a high technology society, there may well be an impending bottleneck in the labor force if we do not upgrade substantially the education of the population. This contention is based upon the view that traditional industries are being replaced by ones that use the new technologies, and the new job requirements will entail higher levels of sophistication than those of the old jobs. Some pundits even predict the demise of entry-level jobs requiring little education.

One obvious issue is the role of higher education. Will the new technologies require an unprecedented expansion and renovation of higher education to meet the new challenges? If so, what specifically should be done? The purpose of this presentation is to address these issues by asking where the new jobs will be and what types of policy responses in both the economy and in higher education make sense.

Where Will the Jobs Be?

In considering where the jobs will be and their educational requirements, we must avoid two fallacies that are reflected in popular discussions on the subject. First is the fallacy that equates "high technology" industries with jobs that require high skill levels and advanced education. Second is the fallacy that assumes that the fastest growing job categories in terms of relative growth or percentage growth are also the ones that will provide the most new jobs in the future.

The question of what is a high technology industry is very much open to debate. The U.S. Department of Labor uses three definitions (Riche, Hecker, and Burgan, 1983): (1) Those industries in which technology-oriented workers (engineers, scientists, etc...) accounted for a proportion of total employment that was at least one and a half times the average for all industries; (2) Those industries in which the ratio of R. & D. expenditures to net sales was at least twice the average for all industries; and (3) A combination of criteria (1) and (2). Even when these industries were singled out, only a relatively small portion of jobs in such high tech industries required high tech workers in terms of skills and educational requirements. For example, in electronic components firms, only about 15 percent of the jobs were technologically oriented, while 61 percent were blue collar jobs (Riche, Hecker, and Burgan, 1983:54). What we often tend to forget is that firms that are selling products must hire large numbers of assemblers, clericals, warehouse workers, secretaries, and so on. Even the computer and data processing industry had only one-quarter of its labor force in technically-oriented positions (Riche, Hecker, and Burgan, 1983:54). For the automobile industry, the percentage of such positions was less than 6 percent (Riche, Hecker, and Burgan, 1983:54). The growth of high technology industries does not mean that all or most of the new jobs that will be created will require high levels of technical skills. Most new jobs in these industries will require high school diplomas rather than advanced education and training.

Thus, the concern over education should really focus on the expansion of jobs in high technology occupations and in other higher level occupations, rather than in so-called high technology industries. The most sophisticated job projections have been carried out by the U.S. Department of Labor, Bureau of Labor Statistics (BLS). The BLS has been making such forecasts for almost forty years and has been refining its methods based upon evaluations of the projections with the actual outcomes. The BLS method takes account of alternative economic growth rates, technological change as it affects occupational requirements and production techniques, and a wide variety of other criteria (Rumberger and Levin, 1984). Table One shows the forty occupations with the largest expected job growth from 1982-95 (Silvestri, Lukasiewicz, and Einstein, 1983:45). The top five occupations in terms of the numbers of jobs projected are building custodians, cashiers, secretaries, general office clerks, and sales clerks.

No high technology occupations are included among the top 18 expected to contribute the most jobs to the American economy. Although fast food workers, guards and doorkeepers, kitchen helpers, and janitors are reflected among the top occupations, high tech occupations are far down the list. While it is expected that some 200 thousand additional computer programmers will be needed by 1995, the growth in jobs for building custodians, fast food workers, and kitchen helpers is expected to be more than 1.3 million. The point is that most job growth will be in areas requiring high school completion or less or some community college training. Relatively few jobs will require the skills of a college graduate or post-graduate training. The BLS estimates that only about a quarter of the 40 jobs with the largest expected contribution to job growth will require a college degree.

But, how can these results be reconciled with the persistent messages that high technology jobs are the ones growing most rapidly and that the educational requirements for these jobs will be high? Part of the answer is that, in percentage or relative terms, many of the occupations with the most rapid growth rates are in high technology occupations as shown in Table Two. But, although these job categories are growing at a rapid rate in relative terms, this growth occurs in occupations with numerically small numbers, so that rapid growth rates produce relatively few new jobs. For example, although employment of computer systems analysts is expected to rise by about 85 percent during the 1982-95 period, only about 200,000 new jobs are expected to emerge from this growth.

A second explanation for the puzzle is the assumption that high tech jobs all require advanced education. Although it is projected that the number of jobs for computer operators will rise by 76 percent during this period, it should be recognized that those jobs typically require no education beyond high school completion. This is also true of the increasing number of computer and micro-processor repair positions which use highly sophisticated diagnostic equipment that automatically identifies the problems and simple component and circuit-board construction that enables component replacement with little sophistication.

The BLS has defined high technology occupations to include engineers, life and physical scientists, mathematical specialists, engineering and science technicians, and computer specialists (Riche, Hecker, and Burgan, 1983:54-55). Workers in these occupations typically need advanced training at an associate degree level at a minimum and up through the doctorate in some cases. Although the growth of these occupations will be at a rate about twice that of all wage and salary workers, the actual number of jobs expected to emerge will be about 1.5 million new jobs out of an expected 23-28 million new jobs. It is expected that only about 6 percent of the new jobs in the economy will be in high technology occupations, about the same proportion as in the 1970's (Riche, Hecker, and Burgan, 1983).

But, what of the effects of high technology on other occupations? Will high technology require increased skills in those occupations? The available evidence suggests that the principal impact of micro-processors and robotics on traditional occupations will be to displace some workers and to reduce the skills of other workers. This conclusion is consistent with the work on machine automation done in earlier periods where it was found that new production technologies tend to reduce skill requirements (Bright, 1958; Levin and Rumberger, 1983). This is also logical, since an investment in new capital can only be profitable if it reduces overall costs for any given output. Reduced labor costs can be derived from using fewer people in the production process, using persons with lower skill levels and wages, or some combination of these. It is the latter that seems most applicable, as our analysis of the application of computers and robots suggests. Let me provide a few examples.

Secretaries are being replaced by word processors at a very rapid rate. Traditionally, secretaries had to know the appropriate formats for reports and correspondence and had to be almost letter-perfect in their typing skills. In addition, they needed strong spelling skills and a basic understanding of grammatical usage. However, word processors can correct typing errors automatically, so letter-perfect typing and strong spelling are no longer required. Formats for different types of documents can be programmed into the word processor, and even grammatical revisions can be done through syntactical programs. The result is that many of the traditional functions of the secretary have been replaced by the machine. It should also be noted that the increased productivity of word-processing reduces the need for office workers. Moreover, the shift from a typewriter to a word-processor requires relatively little training. One of the major suppliers of temporary manpower has found that it can prepare typists who lack background on word processing equipment with only one day of intensive instruction.

A second example is found in the field of computer programming. Not only were earlier computers larger and more expensive than today's computers, but they were far more cumbersome to program. The power of the technology itself has displaced much of the earlier skills required of the programmer with the transition from circuit logic and plug boards to machine language, macro-assembly languages, scientific and business-oriented user languages, and the relatively simple languages that are in use today. In increasing numbers of cases, powerful software packages enable highly sophisticated applications to broad classes of problems, with the programmer only required to provide data and select from among a menu of options. And, even present programming languages will be replaced with "natural" languages--the language of the user-- simple mechanical devices such as the computer "mouse", and voice recognition. Although a small number of programmers using the state-of-the-art will require very sophisticated skills, the average programmer will not, and software will replace programmers.

Similar stories can be told for computer and computerized machine repair, data processing, auto repair, design, drafting, and many other occupations. Just as a modern automobile with six or seven micro-processors requires far less skill to drive than a primitive Model T, the vast majority of high technology applications enable a reduction in the skill requirements of the operator. Many workers will be displaced by the new technologies, and far more will see their jobs reduced to ones requiring minimal training and skills. As a portent of this, we should be aware that many American multi-national firms are producing much of their outputs of sophisticated silicon chips in such third world countries as Malaysia, where young women from rural areas with a few years of primary education have displaced American assembly workers.

What Should Be Done

The advent of high technology will increase the capabilities of the economy, reduce prices, offer a large array of new products, and contribute in other ways to our society. Yet, contrary to popular reports, it is not likely to add large numbers of jobs for highly educated and trained persons; it is likely to displace substantial numbers of workers; and it appears to be reducing the skill requirements of broad classes of traditional occupations. What should be done?

General Policies

1- It is clear that we can not rely on high technology to solve the employment problem. Such reliance has actually undermined traditional jobs by ignoring the large number of jobs--even in smoke-stack industries--that are necessary to our economy and that can be saved through judicious policy. First, we must examine which jobs in declining industries, beset by foreign competition, are worth saving and what will be the cost. In many cases, high technology will be part of the solution, since major investments in high technologies can increase productivity enormously. It is absurd to think that the U.S. will produce only information services, computer software, and research and development, and that all of our other goods and services will be imported from lower cost, third world countries. This is the silly vision of some futurists. We will continue to be a major manufacturer of steel and metal products, automobiles, machine tools, and many other basic products. The question is how we can improve our performance and compete more effectively in both domestic and world markets, not how we pursue the purposive abandonment of such industries.

2- Most new jobs are created in small and medium-size firms rather than in the large corporations or in government (Armington, 1983; Greene, 1982; Richman, 1983). To the degree that Fortune 500 firms have increased employment, it has been done largely through acquisitions and foreign subsidiaries. Many of the largest corporations have been reducing employment over the long run while expanding output through labor-saving approaches. Accordingly, we must promote entrepreneurship and the establishment and survival of substantial numbers of smaller businesses. Such businesses not only have greater employment potential, but they also are the major incubators for product innovation in America (U.S. Small Business Administration, 1983:Chapter 5). Government assistance should be provided in the form of technical help, information on markets, and successful attempts to reduce interest rates. Present national deficits and other aspects of national economic policy have kept interest rates high, and this is the largest single enemy of small businesses.

3- The family farm is still the most efficient building block of American agriculture. This has been one of the most consistent findings in the literature on agricultural economics. Such farms are more productive in terms of total factor inputs, and they provide considerably more employment per unit of investment than the large corporate entities. Yet, agricultural policy--and particularly high interest rates--are undermining the family farm while providing the largest benefits from tax policies, agricultural subsidies, and water subsidies (particularly in the West) to the wealthiest corporations in America. Clearly, a more even-handed policy is in order or one that promotes the family-type farm (Humphries, 1980). Such farmers need assistance in terms of access to credit as well as in the application of high technologies that will keep them competitive. This is another area in which overall employment can be maintained or increased.

4- In order to compete better in world markets, we need to have a much more aggressive policy to promote trade. Businesses need more information in a convenient form about foreign markets and the requirements for entering and competing in them. They need assistance at the state level with respect to where the opportunities will be and how to take advantage of them. None of this will easily overcome a strong dollar which makes American goods expensive to foreigners. However, as interest rates come down over the longer run, we must be in a position to exploit the resulting improvement in the attractiveness of U.S. prices to foreign purchasers. Even under existing exchange rates we can generate much more employment in the foreign trade sector.

5- Finally, we need to capitalize on educationally-intensive types of activities. Much of the Japanese successes have been built on continually upgrading the workforce and creating technological change in materials and capital-saving forms rather than labor-savings ones. For example, of process innovations initially introduced between 1945 and 1974, some 61 percent of those introduced in the U.S. were labor-saving as compared with only 16 percent of those introduced in Japan and 18 percent of those introduced in Europe (Davidson, 1976). In contrast, only about 19 percent of such innovations introduced in the U.S. were material saving in comparison with about half in Japan and Europe. Yet, both Japan and Western Europe increased their labor productivity considerably more than the U.S did over this period, despite their failure to adopt labor saving devices at the rate of the Americans. Other examples, of industrially competitive organizations with high labor inputs are the producer cooperative movement of Mondragon in Spain that has produced over a billion dollars a year of industrial and high technology products with far greater labor inputs and higher productivity than comparable firms organized in traditional ways. We must do much more to explore the possibilities of efficient production organizations with high labor inputs and highly trained workers (Levin, 1983).

Educational Policies

1- It is clear that the structure of American industry is changing dramatically with massive repercussions for the workforce. Many workers will be displaced and will need new training to acquire another job, while others will need to be retrained to accommodate new technologies. Retraining does not mean that higher level skills will be needed as much as different ones. In some cases the training will take hours or days, while in other cases the need will be for weeks, months, or even years. A policy of recurrent education must be established to make it easily possible for individuals to move from the workplace to retraining programs and back into the workplace, a system in which education and work follow a recurring pattern. At the present, there are large numbers of federal, state, local, and privately sponsored programs with employers, school districts, community colleges, unions, proprietary schools, universities, and local training entities providing educational and training services. Sources and modes of finance are also highly fragmented. The challenge is to construct an overall system of recurrent education and finance that will be efficient, responsive, and that will draw upon all elements of the post-secondary educational system (Levin and Schutze, 1983).

2- The jobs that will be available to any individual over a lifetime as well as the ones that he or she will find attractive are unpredictable. While job projections can give us some idea of the array of employment opportunities that will be available at a future time, they can not tell us precisely what will be available and what skills will be required for any particular individual situation. Accordingly, I believe that it is important to stress a broad array of fundamental skills in higher education for the vast majority of students--rather than narrow vocational preparation. These skills include written and oral expression, mathematics, sciences, fine and performing arts, analytical skills, social sciences, and foreign languages. These will provide a firm basis for obtaining the applied training that will be needed at each stage of the career.

3- Much more emphasis should be placed on the training of entrepreneurs and on the formation of creativity in virtually all of higher education. This can be done by restructuring courses and curricula to provide greater analytic work in creative solutions to problems as well as providing greater incentives for imaginative solutions in contrast to rote learning. We should also provide incentives and encouragement for greater risk-taking among our students in the subjects that they take, in the nature of the assignments that they do, and in the careers that they pursue. I am convinced that much improvement in the entrepreneurial capabilities of the population can be effected in our colleges and universities.

4- Finally, the abysmal knowledge of foreign languages and cultures does not augur well for our successful competition in world markets. Virtually all students in higher education should be required to obtain proficiency in at least one foreign language and culture, and much of the curriculum should reflect cross-cultural rather than narrow egocentric thinking. If we cannot communicate with and think like people in other cultures, it is unlikely we will respond to their needs and get their business. There is much to do on this front.

A Concluding Remark

The picture that I have painted of the implications of high technology for jobs and higher education is not a bright one. That is, it is not bright if we simply assume that the high technology revolution will provide plenty of jobs for highly trained individuals. However, we can do something about it through conscious choices in both the economic arena and the educational one. Ignoring the problem will lead to serious consequences for both the labor force and the educational sector.

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TABLE ONE

Forty occupations with largest job growth, 1982–95

Occupation	Change in total employment (in thousands)	Percent of total job growth	Percent change
Building custodians	779	3.0	27.5
Cashiers	744	2.9	47.4
Secretaries	719	2.8	29.5
General clerks, office	696	2.7	29.6
Salesclerks	685	2.7	23.5
Nurses, registered	642	2.5	48.9
Waiters and waitresses	562	2.2	33.8
Teachers, kindergarten and elementary	511	2.0	37.4
Truckdrivers	425	1.7	26.5
Nursing aides and orderlies	423	1.7	34.8
Sales representatives, technical	386	1.5	29.3
Accountants and auditors	344	1.3	40.2
Automotive mechanics	324	1.3	38.3
Supervisors of blue-collar workers	319	1.2	26.6
Kitchen helpers	305	1.2	35.9
Guards and doorkeepers	300	1.2	47.3
Food preparation and service workers, fast food restaurants	297	1.2	36.7
Managers, store	292	1.1	30.1
Carpenters	247	1.0	28.6
Electrical and electronic technicians	222	.9	60.7
Licensed practical nurses	220	.9	37.1
Computer systems analysts	217	.8	85.3
Electrical engineers	209	.8	65.3
Computer programmers	205	.8	76.9
Maintenance repairers, general utility	193	.8	27.8
Helpers, trades	190	.7	31.2
Receptionists	189	.7	48.8
Electricians	173	.7	31.8
Physicians	163	.7	34.0
Clerical supervisors	162	.6	34.6
Computer operators	160	.6	75.8
Sales representatives, nontechnical	160	.6	27.4
Lawyers	159	.6	34.3
Stock clerks, stockroom and warehouse	156	.6	18.8
Typists	155	.6	15.7
Delivery and route workers	153	.6	19.2
Bookkeepers, hand	152	.6	15.9
Cooks, restaurants	149	.6	42.3
Bank tellers	142	.6	30.0
Cooks, short order, specialty and fast food	141	.6	32.2

Note: Includes only detailed occupations with 1982 employment of 25,000 or more. Data for 1995 are based on moderate-trend projections.

Source: Silvestri _et_ _al_. 1983:45

TABLE TWO

Twenty fastest growing occupations, 1982–95

Occupation	Percent growth in employment
Computer service technicians	96.8
Legal assistants	94.3
Computer systems analysts	85.3
Computer programmers	76.9
Computer operators	75.8
Office machine repairers	71.7
Physical therapy assistants	67.8
Electrical engineers	65.3
Civil engineering technicians	63.9
Peripheral EDP equipment operators	63.5
Insurance clerks, medical	62.2
Electrical and electronic technicians	60.7
Occupational therapists	59.8
Surveyor helpers	58.6
Credit clerks, banking and insurance	54.1
Physical therapists	53.6
Employment interviewers	52.5
Mechanical engineers	52.1
Mechanical engineering technicians	51.6
Compression and injection mold machine operators, plastics	50.3

Note: Includes only detailed occupations with 1982 employment of 25,000 or more. Data for 1995 are based on moderate-trend projections.

Source: Silvestri et al. 1983:46

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HIGH TECHNOLOGY AND JOB LOSS

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This paper is the third report produced under the IFG Project, "The Educational Consequences of High Technology," directed by Henry M. Levin and Russell W. Rumberger. The previous two papers, "The Educational Implications of High Technology" and "Forecasting the Impact of New Technologies on the Future Job Market," can be ordered from IFG.

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Abstract

Technology creates jobs, but it also eliminates them. These two outcomes raise two important questions: Does technology create more jobs than it destroys? Does technology create more higher-skilled jobs than it destroys? Evidence suggests that future technologies may provide different answers to those questions than past technologies. In the past, technology primarily displaced unskilled, physical labor in some sectors of the economy, while economic growth created more than enough jobs to offset those displaced by technology. In the future, however, technologies based on micro-electronics threaten to displace skilled, mental labor in all sectors of the economy, while continued increases in productivity may limit the ability of the economy to generate enough new jobs to offset those displaced by technology.

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> There is, of course, not a scrap of evidence in either theory or history to suggest that technological development won't increase employment and real incomes today just as it always has.
>
> -Bruce Bartlett, Executive Director,
> Joint Economic Committee of Congress (1984)

> For millions of Americans, job opportunities are being destroyed by a fierce combination of forces, the most threatening of which is technology. The time has come to worry about automation again. After 1990, when current technology has gone through more than half its expected development, it will take perhaps 75 percent of the work force to do 100 percent of the work.
>
> -Gail Garfield Schwartz and William Neikirk,
> The Work Revolution (1983)

Technology is transforming work throughout the economy. Many workers are now using computers, word processors, and other electronic products to perform their jobs faster and more efficiently. Other workers are simply being replaced by machines. Automatic teller machines are eliminating jobs for bank tellers. Robots are replacing a variety of workers on the assembly lines of American factories. Direct dialing equipment is greatly reducing the number of telephone operators. Even airline pilots are not immune to replacement by machines: the new generation of aircraft, the Boeing 757 and the 767, requires 2 instead of 3 persons in the cockpit.

Some people view these developments with great alarm. The loss of jobs due to machines is taking place in all sectors of the economy and appears to be accelerating. Even more alarming than the present trends are the ominous prospects for the future. The development and application of new machines, fueled by the greatly reduced price and greatly increased capacity of micro-electronics, promises no end to the replacement of men and women by machines. With recent unemployment levels already at very high levels, millions of workers could remain unemployed in the future.

It is not only the number of jobs being lost to machines that generates concern, but also the kinds of jobs. Past technological developments largely displaced physical labor on the farm, in the factory, and in the home. But new technological developments, especially those based on micro-electronics, are largely displacing mental labor in all sectors of the economy. As computers become cheaper and more sophisticated, they will be capable of replacing workers in more sophisticated jobs. Not only bank tellers and telophone operators can be replaced by machines, but so can pilots and industrial designers.

Others see little reason to view these developments with any concern. Technology has always displaced workers from jobs in certain occupations and industries. But employment in other areas of the economy has always expanded to provide new jobs. The decline in agricultural employment during the first half of this century was accompanied by increased manufacturing employment. The service sector has more recently provided the bulk of new jobs as manufacturing employment has leveled off. While machines will always eliminate some jobs, economic growth will generate enough new jobs to absorb those workers in other sectors of the economy.

The fears and concerns about job loss from technology are not new. They began during the early days of the industrial revolution in England, as men began to be replaced by machines:

> Perhaps most obvious of all was the unemployment of displaced craft workers, only slowly absorbed by the expanding factories. Such unemployment (at this period) was only temporary, but was nevertheless serious to those displaced. Machines, it seemed, were the cause of that unemployment. They did work formerly requiring many hands. Small wonder that the craftsmen at times turned against these machines (Lilley 1965, p. 111).

Fears of job loss have continued ever since. The fears generally become more widespread during periods of high unemployment. They arose during the Great Depression. They arose again during the late 1950s and early 1960s as more and more factories began to automate and the national unemployment rate climbed to over 6 percent.

The concerns over job loss from technology during this last period grew from the ranks of union officials as their members feared for their jobs. Soon the concerns were voiced from government officials. President Kennedy stated at a press conference in 1962:

> The major domestic challenge of the Sixties is to maintain full employment at a time when automation is replacing men. It is a fact that we have to find over a ten-year period 25,000 new jobs every week to take care of those displaced by machines and those who are coming into the labor market (quoted in Dunlop 1962, p. 1).

These concerns prompted President Johnson to create the National Commission on Technology, Automation, and Economic Progress in 1964. It also generated a host of national conferences and widespread scholarly inquiry into the issue of technological unemployment.

As these deliberations began, the national unemployment rate dropped to under 5 percent. Not surprisingly, perhaps, most of the research produced in this period reached the same conclusions as the National Commission (1966):

> Thus technological change (along with other forms of economic change) is an important determinant of the precise places, industries, and people affected by unemployment. But the general level of demand for goods and services is by far the most important factor determining how many are affected, how long they stay unemployed, and how hard it is for new entrants to the labor market to find jobs (p. 9).

The concern over technological job loss has now resurfaced, triggered by the recent recession and the highest unemployment rate since the 1930s. But again many people view the recent displacement as only a temporary condition affecting workers in only certain sectors of the economy, such as steel and automobile manufacturing. The most common response to those displaced by machines is that the future should be no different from past periods of displacement: economic growth will eventually produce enough jobs to replace those lost to machines.

Yet the past may be a poor guide to the future. First, new technologies, based on sweeping developments in micro-electronics, are likely to eliminate many more jobs in the future than past technologies did. Past technologies largely eliminated unskilled jobs in agriculture, construction, and some areas of manufacturing. New technologies threaten jobs in the factory, on the farm, and in the office. Much of this displacement will take place in the service sector, where most new jobs have been created over the last few decades.

Moreover, these technologies threaten to displace high-level, mental jobs as well as low-level, physical ones.

Second, the economic environment in which these changes are taking place is also different from times past. The U.S. no longer dominates the world marketplace. Many nations, including developing countries, can now produce even sophisticated, technical products that compete with those produced in the U.S. The United States is thus being challenged in both the world market and the domestic market for goods. Foreign producers have already captured a large share of the domestic market in steel, automobiles, and consumer electronics.

American firms, in order to remain competitive, are setting up manufacturing facilities in other countries to take advantage of lower labor costs. This movement has been facilitated by technological developments in transportation and communication, as well as manufacturing techniques that allow low-skilled, low-wage labor to produce even the most sophisticated electronics devices. American workers not only must fear for their jobs because of technology, but also because of foreign workers paid by American companies.

This economic climate, together with the current fiscal problems of large budget deficits and high interest rates, may undermine the nation's ability to sustain enough economic growth to offset the loss of jobs from technology and the movement of jobs overseas.

The remainder of this paper examines the issue of technology and job loss in greater detail. First, it examines the problems in assessing the impact of technology on job loss and job creation. Then it examines the employment impact of technology in the recent past. Finally, it examines future employment effects and discusses why they will differ markedly from those that have taken place in the past.

Assessing the Employment Impact of Technology

Technology both destroys jobs and creates new ones. Although it is easy to identify particular cases where technology has had a positive or negative effect on employment, it is much more difficult to identify and measure the overall outcome of these processes throughout the economy.

One difficulty is that technology affects employment both directly and indirectly. Direct effects are generally easy to identify. The introduction of automobiles, for example, created new jobs in the automobile industry and eliminated jobs for blacksmiths and wagon builders. In some cases the employment effects are due to a particular technology; in other cases they may be due to a number of interrelated or cumulative technical developments (Rosenberg 1982, Chapter 3).

Technology also affects employment indirectly. The increased use of automobiles helped to create jobs in petroleum, rubber, steel, and a number of other industries that provided goods used in their manufacture and services used to maintain them. While such indirect effects may be easy to identify, it is more difficult to assess the actual number of jobs created, especially since most are in other industries or sectors of the economy.

It is even more difficult to assess the income and price effects of technology. If technical improvements lower production costs, firms can lower prices and increase sales, thereby creating more jobs. Firms can also raise wages, which would increase consumer spending and sales of other goods and services in the economy. But again it is easier to identify this effect than to measure it. Many economists argue, for example, that technology has greatly increased the level of material well-being in contemporary economies (e.g., Rosenberg 1982). Economist Edward Denison estimates that advances in knowledge, including technology, together with other unexplained factors accounted for one-third of the nation's economic growth between 1929 and 1976 (Denison 1979, Table 7-1). Yet no one has been able to single out the contribution of technology alone.

Another difficultly is that other factors affect employment besides technology. Employment shifts can occur because of secular changes in consumer tastes or because of cyclical changes in consumer income.

Even more difficult than assessing the direct and indirect employment effects of technology is assessing its net impact. It is very clear that technology destroys jobs. And it is equally clear that it creates jobs. What is unclear is whether technology destroys more jobs than it creates. At this point, neither the theoretical literature nor the empirical literature is able to resolve that important issue. But the issue has attracted widespread research and debate.

As economist Robert Heilbroner points out in a review of the historical debate, the question of the employment impact of technology began with Adam Smith more than 200 years ago (Heilbroner 1962). Technology, according to Smith, was the key to creating the "wealth of nations." Through technical development and the division of labor, goods could be produced for lower cost, thereby increasing sales and ultimately employment. Other classical economists, David Ricardo and John Stuart Mill, challenged Smith's view. Mill argued that technology may increase production and wealth, but there is no guarantee that it will increase employment (Heilbroner 1962, p. 11).

The debate has continued ever since. But as Heilbroner points out, few economists have devoted much theoretical attention to this issue. Only recently has scholarly inquiry into the causes and consequences of technological development been undertaken (e.g. Rosenberg 1982; Stoneman 1983). Yet the question of the employment consequences of technology remains unanswered. Heilbroner (1962) argues:

> What still lacks is a conception of the technological progress sufficiently broad to comprehend its long-range and its short-range impacts, alive to its secular re-arrangements of society as well as to its mixed creative and disruptive effects on the economy. The objective may well exceed our grasp. But it is certainly the direction of inquiry toward which a review of the historical debate urges us (p. 22).

There have also been attempts to provide empirical evidence about the net impact of technology. Some of the evidence simply consists of historical data on long-run trends in employment, both within sectors of the economy and in the economy as a whole. But as recent government data illustrate, there is no systematic relationship between rising productivity, which is at least partly attributable to technology, and employment in American industry. In some cases rising productivity is associated with declining employment, while in others it is associated with rising employment (U.S. Bureau of Labor Statistics 1983, p. 47).

For the economy as a whole, total output has generally grown faster than productivity, so total employment in the United States has continued to rise. Between 1948 and 1981, for example, economic output increased 3.3 percent per year, while productivity (output per hour) increased 2.4 percent per year (U.S. Bureau of Labor Statistics 1983, Table 4). Employment increased 42 million over this period (U.S. Council of Economic Advisors 1984, Table B-29). But such evidence simply demonstrates that sufficient economic growth can offset any job losses due to technology, not that technology alone necessarily increases employment.

The inability to determine the net employment impact of technology also makes it difficult to determine the effect of technology on unemployment. Much of the concern associated with technology comes from workers who fear for their jobs. The term "technological unemployment" has been used to describe unemployment attributable to technology. Yet technology may cause few workers to become unemployed even if it eliminates many jobs. Technology may simply cause slower employment growth or even no employment growth in an occupation over time. Much of the actual displacement that does occur can be accommodated through turnover and retirement. On the other hand, workers who initially lose their jobs because of slack demand may never be rehired because of automation. Many unemployed autoworkers are now in this position.

While changes in employment or unemployment cannot be attributed to technology solely, unemployment in the United States has nonetheless increased over the last three decades. The U.S. unemployment rate averaged 4.5 percent during the 1950s, 6.2 percent during the 1970s, and over 8 percent during the first three years of the 1980s (Figure 1). These figures suggest that the economy has not been able to generate enough jobs for the U.S. labor force. Unemployment, whatever its causes, remains a serious problem.

Although no comprehensive data exist that measure the overall employment impact of technology throughout the economy, a variety of available evidence can illustrate where past displacement and job growth related to technology has taken place in the economy and what areas of the economy are likely to be affected in the future. A review of this evidence suggests that displacement is likely to become more widespread in the future.

Recent Job Loss from Technology

Job Displacement

Technology can displace labor by reducing the number of people used to produce a given level of output or by reducing the skill levels of the labor required. Both forms of displacement will reduce the labor costs of production. Of course, not all technical innovations displace labor. Some innovations may save material costs or improve the efficiency of capital. But many tend to displace labor, at least in the United States. A survey of process innovations introduced in the U.S. between 1945 and 1974 identified 61 percent as labor saving (Davidson 1976, Table 2).

The following analysis focuses on the number and types of jobs displaced by technology. A subsequent paper will examine the impact of technology on the skill levels of jobs.

Technology can eliminate jobs in several ways. First, it can reduce or eliminate the demand for particular goods or services due to the substitution of competing goods or services. Second, it can reduce employment within particular occupations or even an entire industry through the introduction of machines and processes that reduce labor requirements. And finally, it can facilitate the substitution of foreign-produced goods for those produced domestically. Recent job losses in a number of occupations can be attributed to each type of displacement.

Table 1 shows the occupations with the largest declines in employment between 1972 and 1980. Total employment in the economy increased by 15 million over this period, raising employment in most occupations. But employment in 50 out of 235 occupations declined by more than 2 million jobs, with more than 1.5 million jobs lost in only 10 occupations.

Two of the occupations that suffered declines in this period were in private household service--cleaners and servants and child-care workers. More than 300,000 jobs in these two occupations were lost between 1972 and 1980. At least some of this decline can be attributed to the availability of inexpensive home appliances that provide an alternative to the rising cost of household labor.

Declining employment in two other occupations can be attributed to two specific technologies. Jobs for telephone operators declined by 76,000 between 1972 and 1980 because of more direct distance dialing, improved switching equipment, and increased use of Central Exchange (CENTREX) telephone systems that do not require operators. Jobs for stenographers declined by 61,000 during this period due to the increased use of dictation equipment.

Technology, through the introduction of new machines and production processes, tends to raise productivity of workers, allowing them to produce more goods or services for the same amount of effort. Yet increased sales of goods or services can actually expand employment even as more capital and less labor is used to produce a given level of output. But in some cases, economic output grows more slowly than productivity, thereby reducing employment. Agriculture best illustrates this case. Economic output from the agricultural sector of the economy has increased steadily throughout this century. Agricultural employment, however, has continued to decline over the same period because productivity in agriculture--due to the increased use of machinery, improved farming techniques, and better strains of crops--has grown at a faster rate. Just between 1972 and 1980, employment for farmers and farm laborers declined by almost 400,000 workers.

The last form of displacement is the most difficult to assess. At least some of the increase in international trade can be attributed to technical developments in transportation and communication. Containerized shipping, for example, has cut loading and unloading time 20 times. The average capacity of ships has also grown, while the average crew size has fallen from 49 in 1960 to 32 in 1981, reducing costs (Critchlow 1983, p. 229). Innovations in communications, such as satellites, enable firms to keep closer ties with their international operations.

These developments have contributed to a growing worldwide market for goods and services. And they have led to job displacement from both foreign suppliers and foreign operations of U.S. firms.

Foreign suppliers have captured an increased share of the domestic market for a number of goods. Foreign cars now account for more than one-quarter of all domestic car sales (U.S. Bureau of the Census 1982, Table 1058). Imports of foreign-produced goods have also increased more than exports of domestically-produced goods in steel, consumer electronics, and clothing (U.S. Bureau of the Census 1982, Tables 1490 and 1491).

These shifts have reduced employment in a number of manufacturing industries. Shifts in the balance of trade between imports and exports had a negative impact on employment in 21 out of 52 manufacturing industries between 1970 and 1980, although increasing domestic sales offset these losses in many cases (Lawrence 1983, Table A-2). In several industries, however, including leather products, footwear, steel, and motor vehicles, employment declines due to trade reduced total employment over this period. Increased sales of clothing by foreign suppliers, together with improved textile machinery, has reduced employment for textile workers, for instance. Between 1972 and 1980, almost one-quarter million jobs for textile workers were eliminated (Table 1).

Foreign operations by American firms can also eliminate domestic jobs. In some cases this involves the production of goods for foreign markets. Many U.S. companies now produce most of their goods for foreign sale outside the U.S. At least some of this production could take place in the U.S. Several studies conducted during the early 1970s estimated that up to a million domestic jobs were lost due to investment of U.S. firms overseas (Kujawa 1980, pp. 5-15). Since that time, foreign investment by U.S. firms has grown substantially, increasing from $75 billion in 1970 to $221 billion in 1982 (U.S. Council of Economic Advisors 1984, p. 337). So the loss of domestic jobs has no doubt increased as well, although no recent estimates exist. In other cases American firms produce goods in foreign countries for sale within the United States. Bluestone and Harrison (1982, p. 44) estimate that "twenty-nine percent of all U.S. imports in 1976 came from the output of overseas plants and majority-owned subsidiaries of American multinational corporations."

The movement of production overseas not only arises because of the availability of low-cost foreign labor and improved transportation and communication, but also because of improvements in production techniques. Now foreign workers with little education and training can produce even sophisticated, electronic equipment because of new, automated production techniques. These developments have led a number of American electronics firms to shift production overseas. In February 1983 Atari announced it was laying off 1700 workers in the Silicon Valley of California and moving production to Hong Kong and Taiwan. Since that time, several other electronics companies have laid off American workers in order to move production overseas. These trends are confirmed by a recent report from the U.S. International Trade Commission, which reported that almost one-third of all computer imports in 1980 were actually "re-imports" from American companies located overseas (cited in Pacific Studies Center 1983, p. 2).

In some cases the movement of production overseas is an "invisible" form of displacement. American companies establish or expand foreign plants instead of domestic facilities. In other cases, such as Atari, a domestic plant is shut down and workers laid off in order to move production overseas. The job losses in this case are very visible.

Job Creation

Technology has also created jobs in recent years. Many of these jobs are in computer-related occupations and industries. Between 1972 and 1980, the increased use of computers created 155,000 new jobs for computer programmers, 127,000 new jobs for computer systems analysts, 326,000 new jobs for computer operators. The increased use of a variety of new machines created 256,000 new jobs for health technologists and technicians during this period (Leon 1983, Table 2). The increased sales of computers and other electronic devices also created jobs in industries producing those products. Between 1972 and 1980, employment in office and computer manufacturing increased by 170,000 and employment in electronic components increased by 200,000 (Riche, Hecker, and Burgan 1983, Table 1). Yet these jobs represent only a small fraction of the 15 million new jobs created during this eight year period. Thus this important technology has generated, at least directly, relatively few new jobs in the economy in recent years.

Increased foreign trade and foreign investment have also created domestic jobs. Between 1970 and 1980, employment in several manufacturing industries--engines and turbines, construction and mining machinery, and office and computing equipment--increased substantially because of increased foreign trade (Lawrence 1983, Table A-2). Investment in the United States by foreign firms has also increased during the last decade, creating domestic jobs that have helped to offset the loss of jobs from increased foreign investment by U.S. firms (U.S. Council of Economic Advisors 1984, p. 337). Foreign investment by U.S. firms also creates domestic jobs in the headquarters of these firms and in firms that supply intermediate goods to overseas subsidiaries of U.S. firms (Kujawa 1980).

The Net Impact

Evidence shows that technology has created as well as eliminated jobs in recent years. But what has been the net impact of these changes? No comprehensive estimates exist to answer this question. But several studies have attempted to estimate the net impact of foreign trade and foreign investment.

After examining employment changes due to trade and domestic use in the manufacturing sector of the U.S. economy, Lawrence concludes that shifts in the balance of trade for manufactured goods produced little change in employment between 1970 and 1980. The changing balance of trade caused employment declines in some industries, and employment increases in others. Overall, however, trade had little influence on employment growth relative to the change in domestic use (Lawrence 1983).

Other studies have estimated the net impact of foreign investment. These estimates vary widely depending on the assumption of how much domestic production could substitute for foreign production. If one assumes that, in the absence of foreign production, U.S. firms would lose sales to foreign competitors, then few domestic jobs are really lost. In fact, there would be a net employment increase due to corporate jobs that remain in the U.S. and due to employment generated in industries that supply U.S. overseas affiliates. If one assumes that domestic workers could produce goods for foreign or domestic sales at competitive prices, then foreign investment decreases domestic employment.

Based on 1970 data, estimates range from a net increase of more than 11,000 jobs in the former case, to a net decrease of almost 2 million jobs (Frank and Freeman 1978, Table 4; Kujawa 1980, Table 1). Because direct foreign investment by U.S. firms has increased by more than $140 billion since 1970 (U.S. Council of Economic Advisors 1984, p. 337), the potential job loss from foreign investment is currently quite sizeable. And although investment in the U.S. by foreign companies has also grown during this period, helping to offset foreign investment by U.S. firms and creating domestic jobs, the difference between the two has still increased during the last decade (U.S. Council of Economic Advisors 1984, p. 337).

Types of Jobs

One concern about technology has to do with the number of jobs displaced. Another concern has to do with the kinds of jobs eliminated. Some believe that technology generally eliminates the most boring and mundane jobs in the economy, freeing individuals for more creative and satisfying jobs. Others believe that technology eliminates many skilled jobs as well. Evidence supports both contentions.

Historically, technology has greatly reduced the need for unskilled physical labor. The vast reduction in the labor requirements of agriculture illustrates the labor-saving impact of technology. Much of the physical labor once required in agriculture is now performed by huge machines, such as combines and tractors. Since the beginning of the century, more than 4 million jobs for farm laborers and foreman have been eliminated in the U.S. economy (U.S. Census 1975, p. 139). Machines have greatly reduced the needs for laborers in other sectors of the economy as well. Over the last 70 years, when economic output and total employment have increased many times, jobs for farm and nonfarm laborers have decreased from 30 percent of total employment to less than 6 percent (U.S. Census 1975, p. 139).

But technology has not only eliminated unskilled jobs. It has also displaced skilled, physical labor. Labor requirements in several skilled and semi-skilled craft areas have been greatly reduced by the use of machines. Between 1960 and 1970, for example, jobs for compositors and typesetters decreased by 29,000 due to the increased use of computer-aided, phototypesetting equipment. During the same period, jobs for machinists declined by 125,000 due to the increased use of numerically-controlled machine tools (Dicesare 1975, Table 2). While technology continued to eliminate unskilled jobs over this period, advances in computers and the increased capabilities of machines allowed displacement of skilled, physical labor as well.

How do the new jobs created in the economy compare to the ones displaced by technology? Are they generally more skilled or less skilled than the ones eliminated?

Unfortunately, there is no easy way to make such a comparison. The reason is that skill levels are difficult to define and to measure. It is particularly difficult to compare the physical skill requirements of a craft job with the mental skill requirements of a professional job (Rumberger 1983). One recent study, based on national data that attempt to measure the training requirements of all jobs in the economy, suggests that the aggregate skill requirements of jobs in the U.S. have changed very little over the last two decades (Rumberger 1981).

Another way to compare the "quality" of jobs is through the use of related measures, such as education and earnings. These measures can be used to compare the quality of jobs that have experienced the greatest reductions in employment with those that have experienced the greatest increases in employment. Table 2 shows the top 5 jobs in each category for the period from 1972 to 1980. The list reveals that the jobs are quite comparable: most have below-average earnings and few require any education beyond high school. In other words, the figures indicate that the jobs being eliminated are generally low-skill and low-wage, but that they are simply being replaced by equally low-wage and low-skill jobs.

Other evidence suggests that industrial shifts in the economy have generated low-wage as well as high-wage jobs. Table 3 shows the average earnings of jobs within major industries in 1980. It also shows the proportion of low-wage jobs--those with annual earnings below $10,000--and the proportion of high-wage jobs--those with annual earnings above $20,000--within each category. In mining, for example, 38 percent of the jobs had high annual earnings, while only 12 percent had low annual earnings. In contrast, 61 percent of the jobs in services paid low wages, and only 14 percent paid high wages.

Comparing the earnings of jobs created between 1960 and 1980 with those that existed in 1960 shows that the two groups are quite similar. Seventeen percent of the jobs in the first group fall into the high-wage category, compared to 20 percent in the latter group; 48 percent of the jobs in the first group fall into the low-wage category compared to 46 percent in the second group. This analysis reveals that the new jobs being created in our economy are quite similar to old jobs: there are high-wage and low-wage jobs in each group and many jobs in the middle.

Other studies suggest that recent job creation has favored low-wage jobs at the expense of middle-wage jobs. An analysis similar to the one above showed that 54 percent of all new jobs created in the services sector between 1960 and 1975 (where most job growth took place) had earnings 20 percent or more below average, compared to 38 percent for all jobs in the economy (Stanback, Jr., 1983, p. 17). A recent BLS study reveals that the average earnings of men in the low end of the distribution grew more slowly than the earnings of men at the high end of the distribution between 1958 and 1977 (Henle and Ryscavage 1980, p. 9).

This evidence suggests that the new jobs created in the economy over the last two decades were no more skilled than the jobs eliminated by technology. Technology has eliminated both skilled and unskilled jobs. The new jobs created by technology and general economic growth have also been skilled and unskilled. Overall, the distribution of skills or earnings of jobs in the economy have not changed markedly over the last two or three decades.

Future Job Loss from Technology

Technology is likely to have a more severe impact on employment in the future than it did in the past. First, new technologies threaten to displace many more jobs, both skilled and unskilled, in the future. Second, it may be more difficult for the economy to generate enough new jobs because of the continued substitution of capital for labor in production and because of an increasingly competitive world marketplace for goods, services, and labor.

Job Displacement

Future job displacement is likely to be different from past job displacement because the technologies affecting displacement differ greatly. Past technologies, fueled by the development of powerful machines, primarily displaced unskilled, physical labor and, to a lesser extent, skilled labor in some craft areas. But future technologies, fueled by the micro-electronics revolution, will displace mental as well as physical labor at both skilled and unskilled levels. Moreover, this displacement will not be concentrated within particular jobs and industries, as in the past, but will occur throughout the economy.

Recent and expected developments in the capacity, cost, and size of micro-electronics have greatly increased the labor-displacing potential of this technology. Advances in solid-state, micro-electronics technology have reduced the cost and increased the capacity of silicon "chips" and the computers in which they are housed by many orders of magnitude. By 1975 a $4 micro-processor that could fit on a fingertip had the computational power of an IBM computer that sold for $30,000 in the early 1960s and whose processing unit occupied the space of an office desk (Bylinsky 1980, p. 7). Today a $4,000 micro-computer the size of a small suitcase has the capacity of a $250,000 mainframe computer the size of a small room in 1970. Future developments are likely to reduce the cost and increase the capacity of today's computers several order of magnitudes further.

The small size, high capacity, and low cost of micro-processors and computers have prompted their widespread use and application in the home and the workplace. Cars, home appliances, and most other consumer products are now equipped with micro-processors that can remember a host of preset commands and respond to a variety of conditions. Computers and other sophisticated, micro-electronics devices are transforming work throughout the economy.

In some cases, the increased use of these machines allows workers who use them to perform the work of many other workers. It has been estimated, for example, that a secretary with a word processor can perform the work of two secretaries with electric typewriters (Dowing 1980). In other cases, machines can simply replace workers in particular occupations altogether. Robots, for example, can replace 2 to 3 workers on the assembly line (Howell 1984, p. 9).

Because the field of micro-electronics is changing so rapidly, it is difficult to estimate the displacement impact of particular devices based on this technology. New devices and applications are appearing almost daily. But it is possible to identify particular occupations and classes of jobs that could face displacement from micro-electronics devices. A few of these technologies and the occupations they affect are illustrated in Table 4.

One well-publicized device is the industrial robot. Robots perhaps best illustrate the displacement capabilities of machines because they emulate all the actions of workers: they sense changing physical conditions, they process this information along with a body of stored knowledge, and they respond accordingly; they can even learn from their experiences. While robots in the U.S. currently number fewer than 3,000, their population could increase to over 100,000 by 1990, eliminating jobs for painters, welders, assemblers, and other operatives. Long-range estimates suggest that robots could replace up to 3 million operatives over the next 20 years and could eliminate as many as 8 million operative positions by the year 2025 (Ayres and Miller 1982, p. 42).

Another labor-displacing development is the automatic teller machine. These machines are now found in banks throughout the U.S. Originally installed to supplement the work of branch banking offices, many banks are now replacing branch offices with newer, more powerful versions of these machines. Bank of America, one of the largest banks in the United States, recently announced it was closing 120 branch offices and eliminating 5,000 jobs in California by consolidating its branch offices and expanding the use of automatic teller machines (San Francisco Chronicle 1983, p. 37).

Labor displacement is also occurring in the engineering field. Drafters are being eliminated by CAD/CAM--computer-aided design and computer-aided manufacturing--equipment. This computer-based device allows engineers to design and redesign any type of large or small product on a computer screen and then have the system produce final working drawings (Gunn 1982). One recent employment forecast predicts that the occupation of drafter could be completely eliminated by the year 2000 (Leontiff and Duchin 1983, p. 4.19).

These three technologies are likely to affect only a limited number of workers in a few selected occupations, at least in the near future. But other technologies, including some that are just beginning to be introduced, could displace millions of workers in the future.

One such technology is office automation equipment--micro-computers that perform a variety of office functions, such as word processing, financial analysis, and filing. A large fraction of the current work force is employed in administrative support occupations--secretaries, bookkeepers, file clerks--that perform these tasks. But these tasks can now be performed on computers using sophisticated software packages, greatly increasingly the work performed by each office worker. Equitable Life Insurance reduced its staff in one office from 25 to 3 clerical workers by transferring files to computers (Indianapolis Star 1983, p. 26). As these systems become more powerful and easier to use in the future, administrators, engineers, and managers will be able to do this work themselves, with significantly fewer or even no administrative support personnel.

Two other technical developments--debit cards and teleshopping--although still in their infancy, threaten another class of jobs. Debit cards, which look like credit cards, can be used to make direct cash debits from a customer's bank account, eliminating the need for cashiers to handle cash or approve checks and credit cards. Supermarkets and gas stations around the country are now beginning to use these systems (San Jose Mercury 1984, p. C1). Teleshopping, which allows customers to buy goods using a computer, could eliminate jobs for sales workers as well as cashiers.

A final development--computer-aided diagnostic equipment--could greatly reduce jobs for mechanics. As sales of automobiles, computers, and other devices increases, there is an increased need for mechanics to repair these sophisticated machines. But computer-aided diagnosing equipment can now perform one of the two important tasks performed by mechanics--diagnosing machine malfunctions. Sensing devices and computer programs that analyze the data these devices generate allow instantaneous diagnosis of a failed component or other problem. Many computers and other electronic devices can now diagnose their own malfunctions. Mechanics, technicians, or even users themselves simply have to replace a failed part or make a prescribed adjustment.

As computers become more powerful, cheaper, and smaller, new applications will be developed. The more sophisticated the machine, the more sophisticated the mental functions it is able to perform and the greater displacement effect. In the long run, technology will simply continue to reduce the labor requirements of production:

> Computers and robots replace humans in the exercise of mental functions in the same way as mechanical power replaced them in the performance of physical tasks. As time goes on, more and more complex mental functions will be performed by machines. Not unlike large bulldozers assigned to earthmoving jobs that could not possibly have been carried out even by the strongest laborers or draft animals, powerful computers are now performing mental operations that could not possibly be accomplished by human minds. Any worker who now performs his task by following specific instructions can, in principle, be replaced by a machine. That means that the role of humans as the most important factor of production is bound to diminish--in the same way that the role of horses in agricultural production was first diminished and then eliminated by the introduction of tractors (Leontief 1983, pp. 3-4).

Improvements in transportation, communications, and automated production techniques will continue to spur the development of a worldwide marketplace for goods, services, and labor. In order to remain in that market, U.S. producers will have to become more competitive with foreign suppliers. One way to cut costs and to remain competitive is to move production facilities overseas where wages for foreign laborers average about $1 an hour compared to $9 an hour in the United States (San Jose Mercury 1983, p. 1). The continued use of this alternative by firms such as Atari will further eliminate jobs in the U.S.

Another way to produce competitively-priced products is to automate production in U.S. plants. In these so-called flexible manufacturing systems, computer-controlled machine tools produce the parts, robots handle the materials, and computers control the entire production system. These systems allow small quantities of goods to be produced inexpensively and permits rapid changeover to the production of other products. While such factories may keep American manufacturing in the U.S., they are unlikely to provide many new jobs: a showcase Japanese plant employs only one-tenth the workforce of a conventional factory it replaces; a new General Electric plant will produce one locomotive frame a day entirely by machine when it formerly took 70 skilled machine operators 16 days to produce (Blynsky 1983, pp. 57,60).

The continued growth of the world marketplace is likely to increase job displacement, either because foreign suppliers will encroach on the domestic market or because U.S. firms, in order to remain competitive, will move production facilities overseas or automate production at home. Each of these developments threatens domestic jobs.

Job Creation

Technology will also create jobs in the future. The continued use of computers and other new products will increase employment in firms that manufacture them. And it will increase employment in occupations where people operate and maintain these technical products. But recent employment projections from the U.S. Bureau of Labor Statistics (BLS) suggest that the number of new jobs generated in these areas will actually be quite small.

According to the BLS figures, only 6 percent of the American workforce was employed in electronics and other high-tech firms in 1982 and only 8 percent of the new jobs expected between 1982 and 1995 will be in these industries. Jobs in many computer-related occupations, such as computer service technicians, programmers, and electrical engineers, are expected to increase rapidly in the future. But this rapid growth will actually produce fewer than 1 million new jobs, less than 6 percent of all new jobs expected over this period. The majority of new jobs will be in clerical and service occupations (Rumberger and Levin 1984, Tables 3 and 4).

So technology will create few new jobs in the economy during the next decade, at least directly. The more important issue is whether more jobs will be eliminated by technology than created by technology and general economic growth. One recent forecast suggests that increased technical innovations and their diffusion throughout the economy will lead to a net reduction in aggregate employment. This forecast projected future employment based on three possible scenarios regarding the production and use of robots, word processors, and other computer-based technologies. It was estimated that rapid diffusion of these products throughout the economy could eliminate 20 million jobs by the year 2000, or 11 percent of all the jobs that would exist in the absence of further technological diffusion beyond 1982 (Leontief and Duchin 1983, Table 1.1).

Two recent studies estimated the net employment impact of one particular technology--robotics. These studies examined only the primary employment effects of robots: the jobs created in the economy where robots are produced and used as well as the jobs created from purchases by robot producers, and the jobs eliminated by the use of robots. Both studies estimated a net reduction in the number of jobs: for every job created, between 3 and 6 jobs will be lost (Hunt and Hunt 1983, pp. x-xi; Howell 1984, p. 15).

This evidence suggests that technology, alone, is unlikely to produce enough jobs to replace those that are eliminated. Whether employment will continue to grow in the future enough to offset the jobs displaced by technology will depend on the general vitality of the overall economy. If the economy can grow at a sufficient rate, it can generate enough jobs to offset those eliminated by technology.

Yet this may become harder in the future than it was in the past. As the costs of labor increase and the costs and capabilities of capital goods, especially computers, decrease, more capital and less labor will be used in the production of the economy's output. And the economy will have to grow by a larger amount to produce each new job.

Recent figures for the manufacturing sector illustrate this trend. Economic output from this sector more than doubled in constant dollars between 1960 and 1980, while employment increased by only 20 percent (Table 5). Part of the increase in economic output can be attributed to an 85 percent increase in the amount of capital per worker. As a result of increased capital investment, each worker produced $10,000 worth of goods in 1960, whereas each worker produced more than $17,000 (in constant dollars) worth of goods in 1980. In other words, manufacturing firms required $8,000 in capital and had to sell $10,000 of goods to create a new job in 1960, while in 1980 they required $14,000 in capital and had to sell $17,000 of goods to create a new job. In the future, the costs of creating each new job and the amount of goods that must be sold to support each worker will continue to increase. The same dilemma faces other sectors of the economy, where the amount of capital and the value of goods produced per worker has also increased.

What about the quality of the jobs created and destroyed in the future? In the case of robotics, studies suggest that semi-skilled production jobs—operatives, assemblers, welders, and painters—will be replaced with semi-skilled maintenance and clerical jobs--robot technicians, secretaries, and clericals (Howell 1984, Tables 7 and 8).

For the economy as a whole, recent BLS projections suggest that most future job growth will occur in the service sector, where there is a high concentration of low-wage jobs (see Table 3). These figures also reveal that the jobs with the greatest expected employment declines in some cases are much better than the jobs with the greatest expected employment gains. The top five occupations in each group for the period from 1982 to 1995 are illustrated in Table 6. Some of the jobs with large expected decreases, such as private household workers and farm laborers, require little education and pay below-average wages. But others, university faculty in particular, are very good jobs. In contrast, the jobs with the greatest expected increases are clerical, sales, and service occupations that pay below-average wages and generally require no advanced schooling.

These figures suggest that the future economy will not simply eliminate low-skill, low-wage jobs and replace them with high-skill, high-wage jobs. Rather both high-skill and low-skill jobs are likely to be eliminated and created in the near future. In the long-run, however, computer-based machines are likely to displace higher-order mental labor, especially in high-wage jobs, while the continued growth of the service sector is likely to favor low-skill rather than high-skill jobs.

Summary and Conclusions

Technology both destroys jobs and creates them. It is easy to identify particular cases where technology has eliminated jobs and other cases where technology has created jobs. But other employment effects of technology are less visible and therefore more difficult to assess. For instance, technology has facilitated the development of the world marketplace for goods, services, and labor, contributing to a loss of domestic jobs. Yet technology has also helped to raise productivity and has thus contributed to the growth of the economy and employment.

The inability to assess the total employment impact of technology, both positive and negative, makes it extremely difficult to provide definitive answers to two fundamental questions about technology: Does technology create more jobs than it destroys? Are the skill levels of the jobs created generally higher than the skill levels of the jobs destroyed? The evidence reviewed in this paper can only supply tentative answers to these questions.

Historical evidence shows that productivity increases have been accompanied by increasing employment, which suggests that, in the past, technology has created more jobs than it has destroyed. But such evidence only shows that past economic growth has been able to produce more jobs than technology has eliminated. Evidence also indicates that past displacement primarily affected unskilled physical labor in limited areas of the economy, primarily agriculture, construction, and mining.

Future job displacement, however, is likely to be more widespread than past displacement and will affect skilled, mental labor as well as skilled and unskilled physical labor. Future displacement will be fueled by the current revolution in micro-electronics that permits computer-based machines to perform higher-order mental tasks. These developments will threaten more and more jobs in the future and will displace workers throughout the economy.

Not only will displacement become more widespread, the economy will have greater difficultly in generating enough new jobs to replace those that are lost. The continued substitution of capital for labor in the production of goods and services will require that the economy grow by a greater amount to produce each new job in the future. And in order to remain competitive in the growing world marketplace, U.S. firms will either have to expand overseas production to take advantage of lower cost labor or automate production at home. Either action is unlikely to provide many new jobs.

It is certain that technology will continue to displace labor in the future. What remains uncertain is whether the economy will grow sufficiently to provide enough new jobs to replace those that are lost and to sustain acceptable levels of unemployment. The time may come when society may have to find alternative means for sharing work and distributing the wealth that it generates (Leontief 1982).

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Table 1

Employment in Declining Occupations: 1972-1980

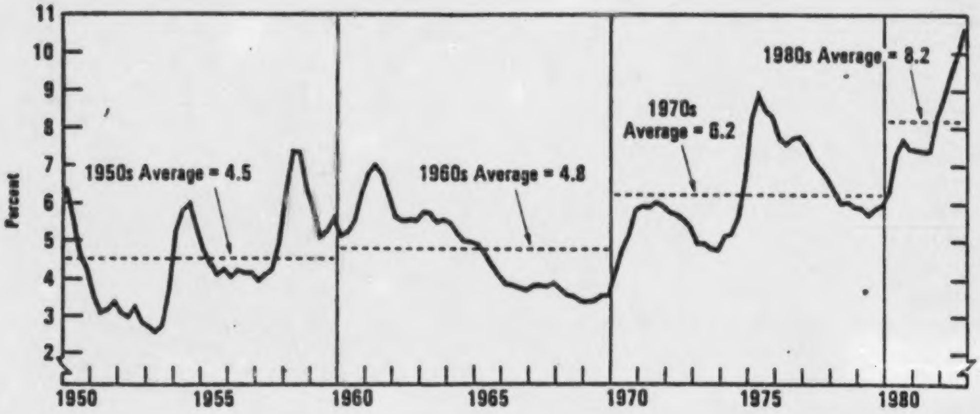
(thousands of workers)

	Employment		Employment Change
	1972	1980	1972-80
Delivery and route workers	892	584	-308
Cleaners and servants	713	491	-222
Farm owners and tenants	1,658	1,447	-211
Farm laborers	455	284	-171
Garage workers	502	337	-165
Sewers and stichers	936	788	-148
Child-care workers (private households)	543	431	-112
Textile operatives	424	323	-101
Telephone operators	392	316	- 76
Stenographers	125	64	- 61

Source: Carol Boyd Leon, "Occupational Winners and Losers: Who They Were During 1972-80," Monthly Labor Review 105 (June 1982), Table 3.

Figure 1

Unemployment Rates for All Workers: 1950 - 1982



Source: U.S. Congressional Budget Office, The Outlook for Economic Recovery, Washington, D.C.: U.S. Government Printing Office, 1983, Figure 25.

Table 2
Employment, Education, and Relative Earnings for the Greatest Declining and Growing Occupations: 1972-1980

	Employment 1972	Employment 1980	Employment 1972-80	Relative Earnings[a] (percent)	Modal Education[b] (years)
	(thousands of workers)				
Declining occupations					
Delivery and route workers	892	584	-308	104	12
Cleaners and servants	713	491	-222	28	<12
Farm owners and tenants	1,685	1,447	-211	119	12
Farm laborers	455	284	-171	53	<12
Garage workers	502	337	-165	60	<12
Total	4,220	3,143	-1,077	76	--
Growing occupations					
Secretaries	2,949	3,876	927	67	12
Cashiers	988	1,554	566	49	12
Registered nurses	801	1,302	501	90	13-15
Cooks	866	1,331	465	48	<12
Truck drivers	1,441	1,844	403	117	12
Total	7,045	9,907	2,862	71	--

---

[a] The average weekly earnings during 1979 of workers in each occupation relative to the average weekly earnings of all workers.

[b] The level of education completed by the majority of workers employed in each occupation in the spring of 1980.

Sources: Employment data from Carol Boyd Leon, "Occupational Winners and Losers: Who They Were During 1972-80," Monthly Labor Review 105 (June 1982), Tables 1 and 3; Education and earnings data calculated from the 1980 Public Use Sample, U.S. Bureau of the Census.

Table 3
Employment and Earnings by Major Industry Group: 1960-1980

	Employment[a]			Earnings[b]			
	1980	1960	1960-80	Mean	Less than $10,000	$10,000-20,000	Greater than $20,000
	(thousands of workers)			($)	(percent distribution)		
Agriculture	2,827	4,685	-1,858	11,813	64	17	19
Mining	1,034	602	432	18,186	12	50	38
Construction	5,189	4,016	1,173	15,350	35	40	25
Manufacturing	21,626	18,539	3,087	14,677	36	39	25
Trans., Comm., Util.	5,631	4,484	1,147	16,520	24	41	35
Trade	19,410	12,181	7,229	10,634	59	27	14
Fin., Ins., R.E.	5,664	2,945	2,719	14,088	49	32	19
Services	18,923	11,043	7,880	11,149	61	25	14
Government	16,730	8,433	8,297	12,377	41	43	16
Total[c]							
1980	97,034			12,919	47	34	19
1960		66,928		13,023	46	34	20
1960-80			33,106	12,651	48	35	17

---

[a] 1980 employment disaggregated into 1960 employment levels and employment growth from 1960 to 1980.

[b] Total annual earnings.

[c] Mean earnings and distribution among earnings classes for each employment category.

Sources: Calculated from the 1960 and 1980 Public Use Samples, U.S. Bureau of the Census.

Table 4

Potential Displacement from New Technologies

Technology	Occupation Affected	Current Employment[a] (thousands)
Robots	Welders	651
	Painters	130
	Assemblers	1,452
	Other operatives	1,863
	Packers	497
	Laborers	1,000
Automatic teller machines	Bank tellers	516
CAD/CAM	Drafters	335
Debit cards	Cashiers	1,667
Teleshopping	Sales clerks	2,802
Computer diagnostic equipment	Mechanics repairers	3,578
Office automation	Secretaries, stenographers, typists	4,508
	Bookkeepers	1,777

[a] Calculated from 1980 Public Use Sample, U.S. Bureau of the Census.

Table 5
Economic Output, Capital Stock, and Employment in Manufacturing and the Total Economy: 1960, 1970, 1980

	1960	1970	1980
Manufacturing			
Output (Billions of 1972 $)	171.8	261.2	351.2
Capital Stock (Billions of 1972 $)[a]	140.4	202.2	293.6
Employment (Millions of workers)[b]	16.8	19.4	20.3
Output/Worker (1972 $)	10,226	13,464	17,300
Capital/Worker (1972 $)	8,357	10,423	14,463
Total Economy			
Output (Billions of 1972 $)[c]	732.0	1,077.6	1,449.3
Capital Stock (Billions of 1972 $)[a]	543.2	860.1	1,226.3
Employment (Millions of workers)[d]	65.8	78.7	99.3
Output/Workers (1972 $)	11,125	13,693	14,595
Capital/Worker (1972 $)	8,255	10,929	12,349

[a] Excludes residential capital and government enterprises.
[b] Wage and salary workers only, based on payroll data.
[c] Gross domestic product
[d] All workers, based on population data.

Sources: U.S. Council of Economic Advisors, Economic Report of the President (Washington, D.C.: U.S. Government Printing Office, 1984), Tables B-11, 29, 37; U.S. Bureau of the Census, Statistical Abstract of the United States, 1982-83, 103d Edition (Washington, D.C.: U.S. Government Printing Office, 1982), Table 903.

Table 6
Employment, Education, and Relative Earnings in the Greatest Declining and Growing Occupations: 1982-1995

	Employment 1982	 1995	 1982-95	Relative Earnings[a] (percent)	Modal Education[b] (years)
	(thousands of workers)				
Declining occupations					
Farm laborers	1,211	1,019	192	53	<12
Private household workers	1,023	850	173	30	<12
College and university faculty	744	632	112	136	17+
Farm owners and tenants	1,407	1,304	103	119	12
Postal service clerks	307	252	55	122	12
Total	4,692	4,057	635	78	--
Growing occupations					
Building custodians	2,828	3,606	778	69	<12
Cashiers	1,570	2,314	744	49	12
Secretaries	2,441	3,161	720	67	12
General clerks, office	2,348	3,044	696	67	12
Sales clerks	2,916	3,601	685	52	12
Total	12,103	15,726	3,623	61	--

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[a] The average weekly earnings during 1979 of workers in each occupation relative to the average weekly earnings of all workers.

[b] The level of education completed by the majority of workers employed in each occupation in the spring of 1980.

Sources: Employment data from George T. Silvestri, John M. Lukasiewicz, and Marcus F. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review 106 (November 1983), Table 1; Earnings and education data calculated from the 1980 Public Use sample, U.S. Bureau of the Census.

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THE BANDWAGON ONCE MORE: VOCATIONAL PREPARATION FOR HIGH-TECH OCCUPATIONS

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May 1984

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Abstract

Vocational education has been no exception to the current preoccupation with the new technologies. Particularly at the postsecondary level, educators are expanding high-tech programs and calling for a further orientation of programs around new technological developments. In one sense this effort is justified because evidence from Texas shows that high-tech sectors do hire large numbers of middle-level technicians who receive a substantial economic return to postsecondary training; on the other hand, the number of middle-level, high-tech jobs that will be created in the next decades will be low. In addition, postsecondary enrollments have shifted rather dramatically toward high-tech programs. Despite the novelty of high technology, several continuities with the history of vocational education have emerged: the overblown promise of vocational education as a panacea, the problem of keeping up with technological developments, the dilemma of providing too-specific training, and the basic confusion over egalitarian goals. These continuities suggest potential problems that will have to be addressed directly in order to avoid the detrimental consequences of the vocational imperative.

Acknowledgments

This paper is part of a larger examination of the vocational roles of schooling, being undertaken jointly with Marvin Lazerson. John Campbell and Susan Goodman of the Bureau of Business Research, the University of Texas at Austin, generously made available some of their preliminary results, described in Section I. Maria Garza-Lubeck and Danielle Jaussaud provided outstanding research assistance.

The technological determinism that suffuses the United States tends to identify new technologies as the generators of economic and social progress. The conventional depiction of the Industrial Revolution as a series of technical developments, increasing general productivity and the standard of living as well as transforming all social institutions, has been repeated for other changes, especially the development of the railroad in the nineteenth century, the development of electric power and the automobile in the early twentieth century, and now the development of micro-electronics.[1] A corollary of technological determinism is the search for technical solutions to social and economic problems, as in the recent infatuation with high technology as a way of increasing productivity, reducing unemployment, rescuing declining regions, and promoting our international competitiveness.

In education, there has been a tendency to view schooling as a panacea for social and economic problems,[2] similar to technological determinism in promoting for solutions that have little to do with the causes of problems. The current concern with the ways schools should be transformed to promote high-tech development therefore combines two powerful strands of thought about social and economic improvement. This combination is in some ways more potent than each individual strand, because it allows educators to claim the rhetoric of economic development for the schools, and gives the schools a centrality and "relevance" that can no longer be claimed for moral and intellectual development. Small wonder, then, that educators cannot resist jumping on the high-tech bandwagon.

Much of the debate over the role of education in high technology has emphasized the shortages of M.A.s and Ph.D.s, and the need in elementary and secondary education for improved math and science instruction. Not surprisingly, however, vocational education has also been affected by the current preoccupation with training for high-tech occupations. Vocational programs provide special opportunities to examine the changes within the schooling system, because they are tied more explicitly to economic imperatives and are less constrained by conceptions of academic or liberal education.

Within vocational education, the most important developments are now taking place at the post-secondary level, especially within community colleges. In 1980-1981 post-secondary programs accounted for perhaps two-fifths of all vocational enrollments.[3] The importance of post-secondary programs, rather than the high-school programs that have always been the heart of vocational education, may be even greater than these numbers indicate, since a great deal of secondary vocational enrollment is really avocational (in automobile repair courses, homemaking, and typing). In addition, there is now substantial evidence that the rate of return to secondary vocational education over alternative curricula is generally zero, while the evidence on post-secondary vocational programs is at least mixed.[4] While high-school vocational ed has increasingly come under attack, post-secondary programs have been the most robust educational sector of the past decade.

The evolution of the community college is itself an arresting development. Over the past two decades community colleges grew faster than any other level of schooling. Between 1970 and 1980 enrollments in two-year institutions grew by 114%, while the rest of higher education grew by a modest 19%; by 1982 community colleges accounted for 38% of enrollments in higher education.[5] (Even during the 1960s, community colleges increased by 261%, compared to 89% for four-year institutions.) As the community college expanded, its central purpose changed from a predominantly academic institution leading to a four-year college to a vocational institution with terminal degree and certificate programs.[6] Currently, there is substantial agreement that two-year institutions have become predominantly vocational rather than academic, although the data to substantiate this trend remain elusive.[7]

Other levels of American education provide close parallels to the growth of the community colleges during the 1960s and 1970s.[8] Between 1890 and 1920 high school enrollments grew rapidly, and the high school became (after considerable debate) increasingly vocational rather than academic--both in the sense that explicitly vocational curricula developed, and in the more general sense that educators promoted the high school as a way to get jobs. The expansion of four-year institutions in the post-World War II period followed similar patterns, with a shift towards more explicitly vocational curricula like business, engineering, and nursing. The developments in the community colleges are therefore part of a larger process, affecting all levels of the educational system, by which schooling has become increasingly vocationalized.

Given the vocational roles of the community colleges and the attraction of high-tech development, it is not surprising to see post-secondary vocational education turning increasingly to preparation for high-tech occupations. The journal of the American Association of Community and Junior Colleges (AACJC) is filled with stories of programs being developed in exotic specialties like robotics, laser technology, and computer assisted drafting (aided with grants of equipment from IBM), as well as more "conventional" courses in computers and electronics; high rates of growth in energy-related technologies have also been reported.[9] Many of these developments have latched onto the rhetoric of economic development that has become common for the rest of education; the robotics program at the Oakland (Michigan) Community College has been justified as contributing to "Michigan's salvation" by replacing jobs lost in the auto industry,[10] and the president of a community college in an area of high unemployment declared that "The development of high technology programs represented our very best hope, not only of attracting new industry to our area, but for helping existing industry compete and prosper".[11]

The rhetoric and plans of community colleges have become equally obsessed with high-tech developments. The AACJC's analogue to the report of the National Commission on Excellence in Education, a "concept paper" entitled "Putting America Back to Work", directed special attention to the "current and predicted skill shortage areas of employment opportunities, particularly in high-technology occupations" like computer analysts and programmers, computer software engineers, and electronic technologists.[12] The conventional wisdom that the United States is moving from an industrial and service economy to an "information economy", with a predominance of "information employees" requiring more training and high-tech skills, has been cited as a special challenge and opportunity for community colleges.[13]

Just as every other level of education has begun to search for new sources of funds to support high-tech education, community colleges have developed initiatives for new federal programs and for business-education cooperation. The Governmental Relations Commission of the AACJC recommended new federal initiatives for "human resource development", defined as "retraining employed workers in high technology and service occupations; upgrading workers for new technologies; strengthening basic skills and technological knowledge of military recruits; and improving workers' productivity to offer an improved competitive posture".[14] The AACJC's Council for Occupational Education has developed a high-technology technician training act which provides tax incentives for private corporations to develop partnerships with community colleges, as a way of training and upgrading technicians.[15] The rhetoric of "partnerships" with business and industry is ubiquitous; partnerships are both the means of securing hardware and instructors in rapidly-developing high tech fields and ways of providing specific training for--and thus securing jobs in--new and expanding companies.[16]

All the themes and slogans that have preoccupied the rest of the educational system have influenced developments in post-secondary vocational education as well. At every level, the same questions apply: Is the current infatuation with education for high-tech occupations reasonable and justified? Will graduates of these programs find well-paid employment in their fields of training, or will programs in post-secondary high tech areas follow the common pattern of other voc ed programs, providing little economic advantage to their students? Above all, does the dawning of high tech mean a real transformation in schooling, or a continuation of older patterns?

In this paper, I will first examine some aspects of the demand for high tech voc ed, by using data on technician-level employment to examine the truth of several conventions about high-tech occupations. I will then look at the supply of students in post-secondary voc ed programs, to see how important high-tech has been in the expansion and development of post-secondary institutions. Finally, I will examine some powerful continuities of high-tech vocational education with the history of vocational education, as a way of identifying potential pitfalls.

Patterns of Demand for High-Tech Vocational Education:

Evidence from Texas

Community college advocates have argued that their institutions are most appropriate for imparting "middle-level" skills. They have offered a simple explanation for growth in post-secondary vocational education: jobs requiring middle-level skills have grown faster than other jobs, and the skills for these job are more appropriately learned in two-year colleges than in the high school or in four-year institutions.[17] These middle-level occupations include a large number of technicians, paraprofessionals, semi-professionals, foremen, and skilled clerical and craft workers. One description of these middle-level occupations includes the following characteristics:

1. They require training beyond the high school level;
2. They require some theoretical knowledge of mathematics and science equal to the first year or two of a professional program;
3. They require training in the development of manipulative skills for using delicate and precise laboratory instruments and equipment;
4. They often require that a person have personality characteristics which allow him to understand human behavior, especially if he is employed in a supervisory position or in a social-service or human-relations occupation;
5. They train students as assistants to professional workers or administrative officials.[18]

Often, the growth of such occupations has been credited to technological developments, with computer-related jobs and health technologies given as common examples of new and expanding occupations generated by technical advances. In this conventional view, occupational demand due to technical change leads directly to increased enrollment, with the implication that community college students then obtain jobs in the areas for which they have been trained.

However, two conventional wisdoms imply that high-tech sectors may not increase the demand for the technicians requiring the "middle-level" skill, associated with community colleges.[19] The first holds that technological developments generate jobs with higher skills, requiring additional schooling and resulting in higher pay and better working conditions; the usual implication is that high tech sectors increase the demand for college and graduate education. The second convention--developed partly in reaction to the first--is that high-tech sectors have a bi-modal occuptional distribution, dominated at one end by highly-trained professionals with college or post-graduate degrees, and at the other end by low-skilled assemblers with little training. The existence of a bi-modal distribution has been used to puncture the claim that high-tech occupations are all highly-skilled, well-paid, and offer good working conditions. For education, the implication is again that the real demand will be for individuals at the B.A. level and above, two-year institutions are irrelevant except to insure a large pool of individuals having science and math prerequisites for advanced programs. If either of these conventions is correct, then the benefits of post-secondary voc ed programs for high-tech occupations may be negligible, because both of them imply relatively little demand for middle-level training.

There are two sources of data relevant to these claims: 1980 census data, which are the more detailed but also more difficult and expensive to use; and the Bureau of Labor Statistics National Industry-Occupation Matrix, with data for 1970, 1978, and projections to 1980. Table 1 presents 1980 Census data on the employment of four different categories of workers in high-tech and conventional manufacturing sectors, by level of schooling, for the state of Texas.[20] They show quite clearly that the occupational distribution of high-tech manufacturing is not bi-modal. Middle-level occupations, defined as technicians, are more prevalent in high tech manufacturing, since 15.1% of employment in high-tech manufacturing is in technician positions compared to 6.5% in conventional manufacturing. Furthermore, technicians in high-tech sectors tend to have more education, since 41.3% have some college and 18.4% have a B.A. or more, compared to 28.4% and 10.8% in conventional manufacturing. (Professionals and managers also tend to have more education in high-tech manufacturing, since 64.7% have a B.A. or over, compared to 47.9% in conventional manufacturing; however, clerical workers and assemblers in high-tech sectors have less education than their counterparts in conventional manufacturing.) If we consider "middle-level" occupations as those positions filled by individuals with one to three years of college, again there are relatively more of these positions in high-tech sectors--25.4% of total employment, versus 20% in conventional manufacturing, with proportionately more of these "middle-skilled" individuals in professional, managerial, and technician positions rather than assembler and "other" occupations. These data support the contention that high-tech sectors do have somewhat more middle-level positions and generally require more education--both in professional and technical positions, and overall--compared to conventional manufacturing.

Corroboration of these patterns in Texas comes from the BLS Industry-Occupation Matrix. Table 2 gives the fraction of employment in a variety of high-tech sectors (using the "Massachusetts" definition again) employed as technicians and as computer specialists. Compared to employment in all sectors, high-tech sectors hire more technicians and more computer specialists (except for watches and clockwork and miscellaneous transportation industries). Furthermore, the projected growth in the proportion of technicians between 1978 and 1990 is higher in most of these sectors (though in most of them the proportion of computer specialists will decrease). Therefore, the claim that high tech industries have no skilled "middle" in their occupational distributions is again disproven.

The income distribution in high-tech manufacturing also fails to display any evidence of bi-modality. Figure 1 depicts the income distributions in high-tech and conventional manufacturing in Texas. The high-tech distribution has a slightly higher fraction of the highest-paid individuals, but otherwise there is no tendency for these two distributions to be radically different, and no support for the contention that the middle of the income distribution is eliminated by the rise of high-tech sectors.

The income distribution is important to education because it influences the rate of return to different levels of schooling. If there is no middle to the distribution of income, then it is more likely that there will be substantial returns to high levels of schooling, with lower or zero returns to moderate levels of education--the levels of education associated with post-secondary vocational education. Thus, the conclusion that earnings in high-tech sectors follow a conventional distribution suggests that returns to moderate skill levels may be about the same in high-tech and conventional

Table 1

OCCUPATIONAL COMPOSITION OF HIGH-TECH AND STANDARD MANUFACTURING IN TEXAS, 1980

Years of Education	Professionals and Managers	Technicians	Clerical	Assembler	Other	Total
High-Tech Manufacturing						
1-12	7.9% 13.9	12.7% 40.3	15.5% 57.5	45.8% 72.8	18.1% 58.9	47.9
13-15	22.8 21.4	24.7 41.3	15.8 31.1	23.9 20.1	12.8 22.1	25.4
16	60.1 32.5	10.8 10.4	7.2 8.2	9.4 4.6	12.5 12.5	14.6
17+	72.1 32.2	10.1 8.0	3.5 3.3	6.3 2.5	8.0 6.6	12.1
Total	27. 1	15.1	12.9	30.2	14.7	100.0
Standard Manufacturing						
1-12	5.6 25.6	5.9 60.7	11.4 62.9	53.0 80.5	24.0 73.5	67.4
13-15	19.5 26.5	9.2 28.4	17.4 28.5	34.8 15.7	19.0 17.3	20.0
16	52.6 29.7	6.0 7.7	9.1 6.2	14.8 2.8	17.6 6.7	8.4
17+	64.0 18.2	4.9 3.2	7.2 2.5	10.8 1.0	13.1 2.5	4.2
Total	14.8	6.5	12.3	44.4	22.0	100.0

The upper figure of each cell is the row percent; the lower figure is the column percent.

Source: John Campbell and Susan Goodman, *High Technology Employment in Texas: A Labor Market Profile* (Austin: Bureau of Business Research, The University of Texas at Austin, in process).

Table 2

PROPORTION OF EMPLOYMENT IN MIDDLE-LEVEL SKILLED OCCUPATIONS IN HIGH TECH-SECTORS

	All Industries		Ordnance		Office, Accounting Machines		Electric Computing		Electrical Machinery	
	1978	1990	1978	1990	1978	1990	1978	1990	1978	1990
Technicians	1.26%	1.34%	5.00%	5.51%	3.96%	4.37%	7.39%	8.12%	4.92%	4.84%
Computer Specialists	.46	.50	2.38	2.28	3.34	2.75	13.69	11.73	1.04	.88

	Communication Equipment		Professional Scientific Instruments		Scientific Instruments		Optical and Health Supplies		Photo Equipment	
	1978	1990	1978	1990	1978	1990	1978	1990	1978	1990
Technicians	6.27%	7.59%	4.72%	4.75%	5.87%	6.08%	5.52%	5.38%	5.60%	5.32%
Computer Specialists	1.49	1.60	.97	.89	1.06	.99	.61	.56	1.53	1.39

	Watches and Clockwork		Miscellaneous Transportation		Drugs and Medicines		Metal-working* Machinery		Other Electrical* Machinery	
	1978	1990	1978	1990	1978	1990	1978	1990	1978	1990
Technicians	1.23%	.88%	1.37%	1.51%	6.48%	6.18%	2.79%	3.27%	4.76%	4.13%
Computer Specialists	.34	.27	.21	.25	1.11	1.05	.44	.39	.91	.65

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*Not a high-tech sector according to the Massachusetts definition.

Source: Bureau of Labor Statistics, The National Industry-Occupation Employment Matrix, 1970, 1978, and Projected 1990, Bulletin 2086, April 1981, Vol. I, Table 1.

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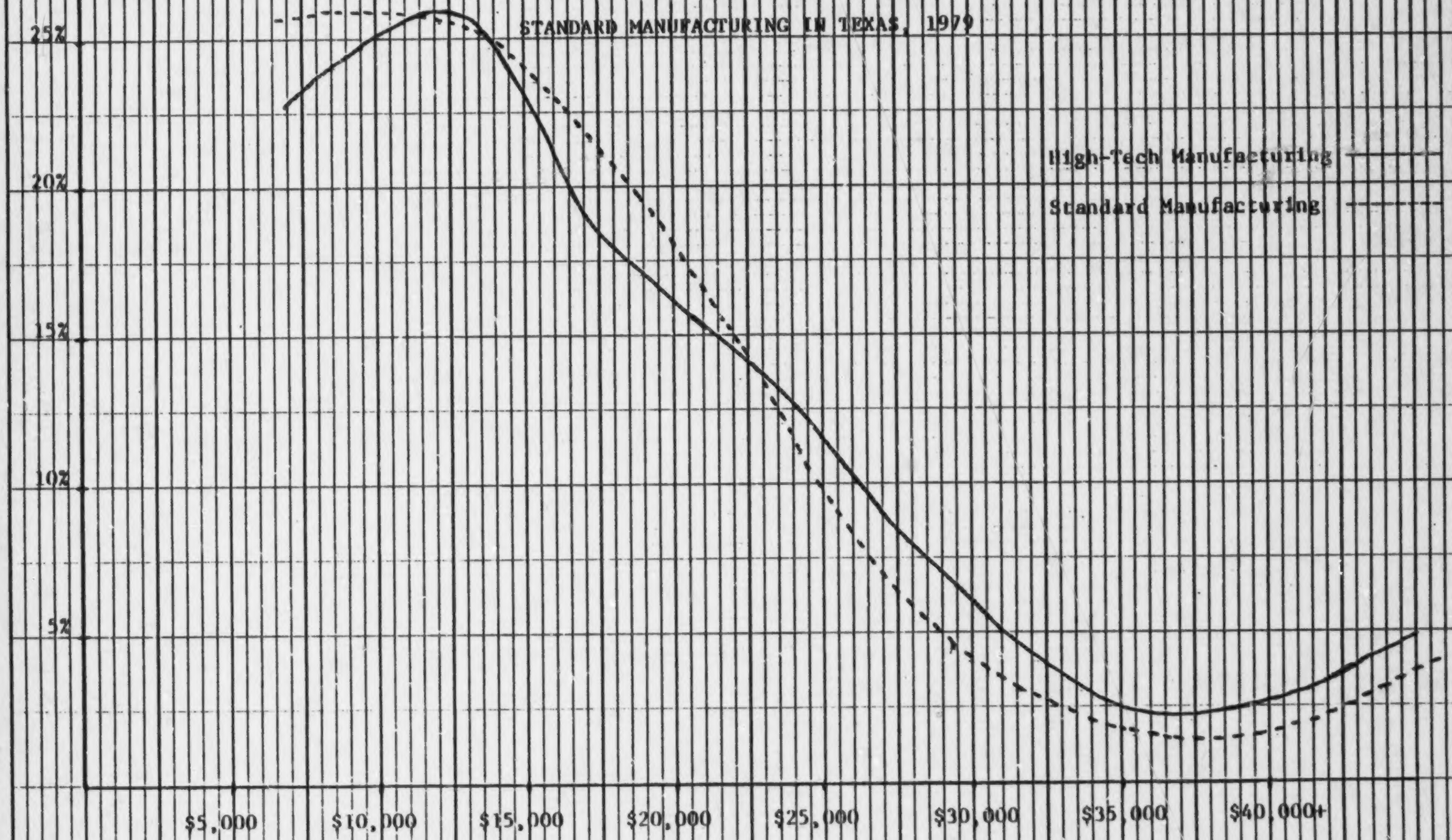
FIGURE 1

INCOME DISTRIBUTIONS IN HIGH-TECH AND STANDARD MANUFACTURING IN TEXAS, 1979



Source: Campbell and Goodman, op. cit.

Table 3

INCOME FUNCTIONS BY SECTOR FOR TEXAS, 1979

	Coefficients of Independent Variables:								
	Post-Secondary	College	Graduate	Male	Black	Hispanic	Log Age	Work 75	R^2
1. High-Tech Manufacturing	.157	.419	.517	.412	-.116	-.195	.369	.178	.55
a. Electrical Machinery	.161	.422	.539	.407	-.125	-.180	.374	.166	.55
b. Office Machines	.096	.353	.393	.467	.013	-.178	.498	.241	.43
c. Computing Equipment	.184	.430	.462	.411	-.085	-.248	.465	.239	.55
d. Communication Equipment	.060	.298	.406	.442	-.117	-.159	.433	.143	.57
2. Standard Manufacturing	.163	.358	.428	.463	-.186	-.255	.253	.187	.41
a. Aircraft and Parts	.135	.326	.411	.312	-.137	-.199	.399	.147	.44
b. Food Products	.173	.390	.495	.369	-.236	-.272	.208	.201	.36
c. Non-electrical Machinery	.144	.327	.435	.445	-.124	-.196	.285	.196	.36
d. Metal Products	.138	.345	.421	.427	-.210	-.240	.271	.196	.33
3. Computer and Data Processing	.068	.293	.329	.396	-.200	-.083	.560	.206	.46
4. Petrochemical Manufacturing	.163	.358	.428	.463	-.186	-.255	.253	.187	.41
a. Oil and Gas Extraction	.110	.391	.499	.419	-.222	-.187	.345	.198	.43
b. Petroleum Refining	.095	.358	.483	.449	-.090	-.118	.275	.191	.40
c. Chemicals	.151	.322	.445	.441	-.170	-.169	.259	.204	.39
5. Retail Trade	.117	.341	.335	.421	-.188	-.206	.192	.228	.34

The dependent variable is the log of income. Post-secondary, College, and Graduate are dummy variables for those with 13-15, 16, and 17+ years of schooling; Male, Black and Hispanic are dummies; Work 75 is a dummy for those who were employed in 1975. Because of large sample sizes, all coefficients are highly significant.

Source: Campbell and Goodman, op. cit.

sectors. Table 3 presents the results of estimating income functions for different sectors of the Texas economy, and confirms this hypothesis: the returns to one to three years of college are almost exactly the same in high-tech and standard manufacturing (.157 and .163), although the returns to a B.A. degree and to post-graduate education are greater in high-tech employment. (There are substantial variations within each of these broad categories; for example, computing equipment has a return in post-secondary education three times the return to communication equipment.) Of course, returns to one to three years of schooling do not necessarily reflect returns to community college programs, but they do suggest that opportunities for post-secondary graduates are not lacking.

These results suggest that any fears about the lack of employment for "middle-level" skill training in high-tech sectors are unfounded, at least in Texas.[21] In this case, the demand for post-secondary education will be determined by the projected growth rates of high-tech sectors and of high-tech occupations suitable for vocational programs. Here the evidence is clear: although the growth rates of high-tech sectors and occupations will probably be relatively high, the numbers of positions created will be rather small.[22] Table 4 presents data on several middle-level, high-tech occupations, taken from the Bureau of Labor Statistics projections to 1995. While the growth rates in these occupations will be high relative to all occupations, the numbers of jobs created in these occupations will equal only about 1,431,000--about 5.6% of the total 25,600,000 jobs that will be created during this period.

The evidence suggests an equivocal conclusion about the demand for middle-level, high-tech positions. The view that high-tech sectors have no substantial demand for middle-level positions seems to be incorrect; therefore, there is some real future for high-tech voc ed. On the other hand, the numbers of such jobs that will be created is now and will continue to be a small proportion of overall job growth, despite high growth rates. The danger is that educators, like the rest of the country, may be easily attracted to high growth rates and so jump on the high-tech bandwagon, ignoring the fact that most of the jobs are likely to be in other, less glamorous areas.

Table 4

EMPLOYMENT IN SELECTED MIDDLE-LEVEL HIGH-TECH OCCUPATIONS, 1982-1995

	Employment (In Thousands)		Growth Rate	Job Increase (In Thousands)
	1982	1995		
Engineering and Science Technicians	1,243	1,661	33.6%	418
Health Technologists and Technicians	627	898	43.2	271
Other Technicians	364	453	24.5	89
Computer Specialists	521	943	81.0	422
Computer Operating Personnel	580	737	27.1	157
Computer Service Technicians	55	108	96.4	53
Engineering Equipment Mechanics	83	94	13.3	11
Instrument Repairers	41	51	24.4	10
Total	3,514	4,945	40.7%	1,431
All Occupations	101,510	127,110	25.2%	25,600

Source: George Silvestri, et al., "Occupational Employment Projections Through 1995", Monthly Labor Review 106 (November 1983): 37-49, Table 1. The 1995 figures in this table are those assuming a moderate growth rate.

Table 5

ASSOCIATE DEGREES AND OTHER PRE-B.A. AWARDS BY CURRICULUM, 1971-1982

	1970-1971	1974-1975	1978-1979	1981-1982	Annual Growth 1971-1979	Annual Growth 1979-1982
Total, All Curricula	307,880	458,532	515,371	560,694	6.65%	2.8%
Arts and Science/General	149,885	171,371	162,663	160,977	1.0	-0.3
Data Processing	8,745	7,886	12,454	27,085	4.5	29.6
Programmers	2,149	2,344	4,122	10,026	8.5	34.5
Operators	387	571	927	1,214	11.5	9.4
Health Services	34,518	76,720	80,022	90,524	11.1	4.2
Nursing	22,116	45,913	50,880	52,511	11.0	1.1
Radiologic, Surgical Optical Technologies	1,463	4,586	6,082	5,627	19.5	-2.5
Mechanical/Engineering Technologies	38,900	56,303	71,288	98,753	7.9	11.5
Automotive and Diesel	4,762	9,203	11,655	13,434	11.8	4.8
Construction	4,229	9,248	10,087	11,576	11.5	4.7
Electronics	7,851	10,834	14,613	25,181	8.1	19.9
Other	22,058	27,018	34,933	48,562	5.9	11.6
Natural Science Technologies	7,028	18,047	19,743	20,016	13.8	0.5
Agriculture	2,870	7,597	8,748	8,373	14.9	-1.4
Food Service	693	2,620	3,789	4,520	23.7	6.1
Business and Commerce	51,037	82,987	121,261	129,881	11.4	2.3
Public Services	12,337	35,218	37,940	33,458	15.1	-4.1

Source: National Center for Educational Statistics, Associate Degrees and Other Formal Awards Below the Baccalaureate, various years.

The Supply of Students in High-Tech Vocational Education

An obvious question is whether the enthusiasm of students for high-tech vocational training matches the vigor of the national rhetoric. The best way to examine the supply of students in post-secondary vocational programs is to look at completers--the numbers of students who have received an Associate of Arts (A.A.) degree or some other formal award in pre-baccaluareate programs.[23] Table 5 presents data on completers for different curricula, between 1970-1971 and 1981-1982.

A remarkable shift in curricula has taken place recently. During the 1970s, the highest growth occurred in relatively conventional fields--in nursing and other low-tech components of health services (like dental assistants and hygienists); in some of the traditional curricula (like automotive and construction trades) within mechanical/engineering technologies; in agriculture and food service; in public services, which include programs for police, firefighters, and child care workers; and above all in business and commerce, which includes various managerial curricula as well as a large number of secretarial programs. Growth rates in high-tech programs--data processing, health technologies, electronics, and the "other" component of mechanical/engineering technologies that includes a variety of potentially high-tech occupations in instrumentation and other engineering-related fields--were modest but not overwhelming, relative to overall growth rates in community colleges. During this period annual growth rates of 6.7% in A.A. degrees were considerably higher than the growth rates of employment--which averaged 2.4% annually between 1971 and 1979. Enrollment in arts and science programs was essentially stable, representing 49% of completers in 1971 but only 32% eight years later, a clear indication of the long-run shift towards vocational programs.

Since 1979, high-tech programs have dominated the growth of community colleges. There has been an upsurge in demand for computer-oriented and other high-tech programs, reflected in both anecdotal evidence[24] and data on completers. Enrollments in data processing, in electronics, and in the "other" component of mechanical/engineering technologies grew much more rapidly than other areas; in fact, growth in these areas accounts for more than the total growth of completers. In contrast, growth in business and commerce, health services, and natural science technologies tapered off, and completers in public service actually declined (as did liberal arts graduates). To be sure, programs that might be considered high tech remain a small fraction of the total: data processing, health technologies, and the potentially high-tech mechanical and engineering technologies account for only 19% of total completers, up from 13% a decade earlier. Thus, we see a pattern within the community colleges similar to occupational patterns as a whole: while high-tech programs have high growth rates, the numbers involved are still relatively small compared to the larger numbers of students in more conventional programs like business, public service, nursing, and liberal arts.

One question from these figures is whether the growth rates in high-tech vocational programs will be sustained. If so, then there is a possibility for post-secondary high-tech programs to follow the high school vocational pattern of "training for unemployment". The growth rate in data processing of 29.6% annually compares with a projected growth rate for computer specialists of 4.7% per year between 1982 and 1995; the growth rate of 14.3% among mechanical and engineering technologists compares with a growth rate of 2.1% among related technicians.[25] Perhaps more relevant is the fact that in many middle-level high tech occupations, the average number of openings--including those due to replacement needs as well as growth--are smaller than the number of community college graduates in related fields. The average number of openings between 1978 and 1990 for computer programmers is estimated to be 29,600, many of them at the B.A. level and over, while community colleges alone graduated about 10,000 in 1981-1982; 16,600 computer specialists are needed per year, while 27,000 graduated from community colleges; 70,900 technicians (excluding health technicians) are needed, while almost 74,000 technicians (excluding automotive and construction technicians) graduated.[26] While it is difficult to match occupations and programs of study precisely, these figures suggest that the numbers of community college graduates in high tech fields may now exceed openings, and that the upward trend in high-tech enrollments could only exacerbate these differences.

If growth rates and numbers of graduates in high-tech programs are higher than in high tech positions--as happened for more conventional curricula during the 1970s[27]--there are several possible outcomes. One is that the "middle-level" high-tech occupations are now going through a cobweb cycle, of the sort that has affected the market for engineers, scientists, and other higher-level personnel.[28] If so, then any tendency for over-enrollments is only temporary, as equilibrium between demand and supply will be re-established once an over-supply materializes, drives down returns to A.A. degrees, and causes fewer students to enroll. However, there is other evidence to suggest that the mechanisms driving demand and supply to an equilibrium may be weak in the community colleges. The information available to students seems to be relatively scant, and the manpower forecasting programs that might allow educators to adjust supply to changing demand conditions are erratic at best. The current infatuation with high tech seems to be generating new programs without much thought to their long-run employment opportunities, as if supply can create its own demand. (This is particularly true of educators trying to use high-tech education as a way to revitalize declining regions.) Finally, students in community colleges seem to respond more to costs than to benefits, implying that the effects of earnings differentials may not be strong enough to equilibrate supply and demand.[29] The history of high school voc ed provides little comfort: it has always been easier to create programs than to reduce or eliminate those that are worthless, and the result has been the prolongation of programs that have outlived any usefulness they might have had.

A second possibility is that a higher fraction of employees in middle-level occupations will have post-secondary vocational training, rather than any other kind of preparation. This may happen in several ways. Community college students may be absored into jobs in place of those with less preparation--a process we can describe either as "skills upgrading" or, more cynically, as credential inflation. Alternatively, they may take the places of those with more training, the process of de-skilling. Indeed, community colleges are ideally placed to benefit from the simultaneous processes of educational inflation--particularly given the failures of high schools--and de-skilling from professional-level positions.

Still a third reason why community college training may come to dominate other forms of preparation is the process of substitution, in which students shift from essentially equivalent programs into community college programs that are cheaper for either employers or for students because of public subsidies. This process of substitution has taken place in nursing, for example, where the fraction of graduating nurses with diplomas from hospital programs has fallen while the proportion with A.A. degrees has increased correspondingly.[30] Because of public subsidies and proximity, community colleges enjoy the advantage of lower cost compared to the alternative forms of training. The effort to socialize training costs--to shift costs from private to public sources, as has happened with nursing programs and with customized training--provides another reason for substitution.

It is too early to say what patterns high tech enrollments will follow, and which of the possible ways of absorbing increased graduates will materialize. However, the experiences of other vocational programs provide some warnings about potential problems for post-secondary programs, particularly in high-tech areas.

Continuities with the Past

The shift of vocational education to the post-secondary level is relatively new, and the emergence of high-tech manufacturing--and the high hopes for its development--are also recent. Still, the current developments in vocational education for high-tech occupations are remarkably consistent with the history of vocational education throughout this century. From a historical viewpoint, these continuities should not be surprising: the development of micro-electronics and other new technologies are not necessarily more startling or disruptive than was the development of new machinery, factory organization, and steam-related technologies in the nineteenth century; the development of electrical machinery and new clerical and managerial occupations at the turn of this century was similarly the cause of great hopes, inordinate fears, and disruption in the schools. Within education, the challenges have been roughly the same since the turn of the century—to prepare students for labor markets, to provide both skill training and those attitudes conducive to productive work and to a particular form of citizenship, and to negotiate between the pressures to use public schooling to equalize opportunities and the pressures to use the schools simply to replicate class patterns over generations. The constancy of technical change and of schooling role has generated a number of similarities over time.

Vocational education as panacea: An obvious similarity between the current burst of concern over education and earlier periods is the tendency to over-promise--to claim that educational reform can solve every social and economic problem. Vocational education has been especially prone to rhetorical inflation, especially in the claims that it can reduce unemployment and poverty, increase productivity and reduce inflation, and improve our international competitiveness. The language of the AACJC's call to arms, "Putting Americans Back to Work", is typical:

> Our nation is experiencing a sense of despair . . . that whatever we do will just not make much difference. Declining productivity, unemployment, and underemployment, stagflation and inflation, high interest rates, and federal deficits have become battering rams causing a staggering impact upon our nation. The mobilization of our human resources offers a way out . . . Our country desperately requires a bold new approach to human resource development. That new approach must be equivalent to the commitment that landed a man on the moon. Our "moon-shoot" for the 1980s must be aimed at the triple goals of ample employment opportunities, increased productivity, and economic health for the individual and the country.[31]

Advocates have also claimed that vocational education can resurrect depressed areas of the country, by attracting new industry (especially high-tech industry) in search of a trained labor force. In North Carolina, for example, the community college system is "the backbone of our economy . . . the single most important element in this program of economic development",[32] and the efforts to develop high-tech training programs as a way to lure high-tech industry to depressed areas--rather than setting up such programs after companies have moved into an area--are other examples of using vocational education in the desperate effort to replace declining conventional manufacturing with high-tech manufacturing.

These are consistent with a long history of claims that vocational education can reduce unemployment, increase productivity, and stimulate international competition. The current preoccupation with besting Japan is similar to the concern at the turn of the century with competition from Germany, which at the time had a well-developed vocational education system that served as an inspiration for the American vocational education movement leading to the Smith-Hughes Act of 1917.[33] The problem with such claims is that they mistake the real sources of economic problems and promise more than vocational programs can possibly deliver. Increasing unemployment has been due more to the substitution of capital for labor, the export of jobs to other countries, and the rise of other countries, trends which vocational programs are powerless to change. Falling productivity has been due to myriad sources, like investment patterns and the shift away from manufacturing towards services and government employment,[34] none of which have anything to do with education policy. Our relative decline in international trade is due more to management errors in key sectors (like automobiles and steel) and to the maturation of countries that had previously been rebuilding from their destruction in World War II than it is to levels of education, in which the United States is still ahead of other countries. Similarly, the decline of regions within the United States and the shift from the North to the South is due to a number of forces--the decline of sectors like steel and automobiles, the search for lower labor costs and other costs of production, the effort to escape unions--that are beyond the scope of vocational programs to reverse. Not only are the economic development efforts through vocational programs zero-sum games--in that they can at best persuade a firm to locate in one region rather than another--but there is little evidence that they are effective.[35]

The most serious problem with over-promising is external to the schools: the claims that education and training can resolve much larger problems draws attention away from solutions that are more precisely addressed to causes. However, inflated rhetoric has also tended to prevent more careful analysis of which educational programs work and which merely depend on rhetoric for their justification. Such over-promising may also draw attention away from the more modest but certainly valuable role that vocational education can play in giving individuals real skills for those "middle-level" occupations that do exist. Over the long run, the cycle of boom and bust--of inflated rhetoric followed by disappointment--often leads to political attack, like the criticisms that emerged during the 1970s of high school vocational education and Great Society programs.

The problem of keeping up: Vocational education has always been plagued with the problem of keeping up with changing production methods and techniques. The charicature of a high-school program, using outmoded equipment, instructors who have not practiced for decades, and methods that have passed from common practice, is part of the criticism that vocational education too often "trains for unemployment". The problem of keeping up with changing methods and materials is especially serious in high-tech areas, because hardware and software change so rapidly and because the costs of hardware are often high. In addition, skilled instructors are often difficult to obtain, because firms are able to pay much higher salaries than are community colleges.[36]

The dominant solution to the problem of keeping up has been to forge alliances with businesses, who can then supply equipment, materials, and sometimes instructors. Whether this solution can keep all high-tech vocational progams up to date is unclear, though it seems doubtful: there appear to be too many programs chasing too few generous firms for the "partnership" solution to work uniformly. However, even if this solution works, it exacerbates a different problem: the tendency for vocational education programs to offer specific rather than general training, in the sense of training tied to one company's equipment and methods.

Specific versus general training: Every evaluation of vocational education since the 1930s has complained that vocational programs provide too much specific training--training that prepares students for a narrow range of occupations, training that can easily become obsolete as occupations and sectors decline or methods change.[37] Yet the charge to make voc ed more general has never been successful, in part because what "general" vocational training might be has never been clear. Instead, educators have been driven towards more specific programs as a way of making their programs seem "relevant" and as a way of increasing placement rates.

Currently, several forces are pressuring post-secondary vocational programs towards specific training: the ubiquitous rhetoric of "partnership" between the public and the private sectors; the need for high tech programs to use equipment and instructors provided by specific firms, with the likelihood that firm-specific methods are taught; and the tendency within all parts of the community college to provide "customized training", programs designed to meet the needs of individual firms. Customized training apparently has something for everybody: it meets the needs of firms for certain kinds of training; the needs of community colleges to generate training programs that contribute to local economic development; and--since students in customized programs often find jobs in the firms for which training is done--the interests of students in employment and of community colleges in high placement rates.

However, there are several drawbacks to such partnerships between schools and firms, whether in the high-tech area or not. One is that, by design, students may be prepared for employment in a particular company, whether through skill training or through socialization to specific company norms; rather than being more broadly trained for a range of allied occupations or for a range of potential employers, a student's future is tied to one company. Second, a student may be narrowly trained to perform a small range of operations, rather than being more broadly training to understand the basic principles of a particular occupation or industry.[38] This again may make students vulnerable to changes in production methods, a problem that is especially serious in high-tech occupations with constant changes in equipment, software, and production procedures. Third, educators have encountered some pressure from business and industry to drop liberal requirements for the two-year degree and to concentate even more heavily on specifically-designed vocational programs, including programs of flexible length that vary from the traditional academic calendar.[39] Finally, the justification for public support of firm-specific training is unclear: in many cases, the development of "partnerships", especially in the form of customized training, looks like a way for businesses to fund their training at public expense. There may be a justification for public funding of general education, but for not the kind of specific training that has become so attractive to post-secondary programs.[40]

The problem of specific skill training may be especially acute in many applications of new technology. Paul Adler has argued that, whether the application of high technology increases or decreases the quantity of skills required, it changes the quality of skills. In particular, new technologies (and especially those based on microelectronics) increase the responsibility of the worker for production, in place of requiring only a "trained gorilla" responsible for rote manual labor; they demand an ability to perform more abstract rather than concrete tasks, since operations involving microelectronics cannot typically be seen and are not concrete in the old-fashioned ways of typewriters, paper output, and filing cabinets; and they require interdependence among jobs (and thus require some understanding of other jobs and encourage team work and job interchangeability) because computer-aided production processes are linked in complex networks, rather than being linked in the simple sequential process of the assembly line.[41]

If these changes in the kinds of skills required prove to be widespread, the most valuable skills in high-tech occupations may be the old-fashioned ones--the ability to think abstractly and symbolically, the ability to understand the underlying structure of interrelated production systems, the personal attributes of responsibility and independence--while specific skill training may be both insufficient and quickly obsolete. The need for such general skills is especially important because of the view, increasingly common, that community colleges are partly remedial institutions:[42] given the failure of high schools, the lack of general skill training in high-tech vocational programs will leave students bereft of the ability to understand the technical complexities they manipulate.

The egalitarian claims of vocational education: The community colleges have claimed for themselves the mantle of equal opportunity, particularly because of their open door policies. As Secretary of Education Terrel Bell declared, "perhaps the most important role [of community and technical colleges] is making post-secondary education accessible to so many who otherwise would have little or no opportunity beyond high school".[43] Typical of the rhetoric of post-secondary educators is the statement that "the community college is the best expression in higher education of the egalitarian ideal of American life: by maintaining an open admissions policy the college fosters our belief in equality of opportunity".[44] Post-secondary institutions are heirs to a similar egalitarian claim made by vocational educators since the turn of the century: that vocational education provides an education to those who otherwise would get none, and that it provides a way of integrating into the economic mainstream those who would otherwise be left out, including women and minorities. Accompanying such rhetoric is a common assertion of moral parity with higher-level "academic" institutions: "We of the community colleges do not believe that there are higher and lower studies, arts that are liberal and arts that are servile--or that education for meaningful work is less worthy than education for meaningful citizenship".[45]

The claim that the community colleges represent the "best expression of the egalitarian ideal" rests on two assumptions: that those who attend community colleges would otherwise have received no further education; and that community college confers an economic advantage over those who do not attend. (A third possibility--that the community colleges are egalitarian because they provide a low-cost mechanism for individuals to progress to a B.A. degree--has been all but abandoned under the conversion of community colleges to terminal vocational institutions.) Both these propositions may be correct, though evidence for them is far from complete.

On the other hand, these egalitarian claims have been overstated. Within the system of higher education, community colleges represent the lowest "track" relative to four-year universities and colleges, with a higher proportion of working-class and minority students; the emergence of the community college has stratified the system of higher education by class and race, just as high school voc ed programs stratified the high school after 1900.[46] Specifically in the area of high tech programs, fears that minority students and women are less well prepared in science and math--and that middle-class students have a head start by having computers in their homes--have generated the suspicion that high-tech voc ed will foster the advancement only of white, male, and middle-class students. Others have expressed fears that the community college is becoming a middle-class institution, especially because of economic pressures.[47]

Some inequalities--especially the position of the community colleges as the lowest "track" within higher education--are caused by pressures external to the community college themselves. Others are more their fault, caused by divisions within post-secondary education. Community college programs are highly stratified by gender, with few women in trade and industrial programs, and few men in "female" areas like secretarial or health technician programs. While minorities tend to be relatively over-represented in community colleges, there is some evidence that blacks tend to be over-represented in the least rewarding programs.[48] Finally, the existing "partnerships" between business and education--including the "customized training" that has become so prominent--tend to be inegalitarian, for the simple reason that many of them take existing employees of firms and provide them additional training; the patterns of racial and gender discrimination that pervade business are thereby replicated in customized training programs as well.

In response to those who promote the egalitarian role of the community college and those who criticize its inequalities,[49] others have denied that equality should be a goal. As two prominent students of the community college declared,

> The real benefit of the community college cannot be measured by the extent to which it contributes to the overthrow of the social-class system in America. Nor can it be measured by the extent to which the college changes the mores of its community. It is a system for individuals, and it does what the best educational forms have always done: it helps individuals learn what they need to know to be effective, responsible members of their society.[50]

The confusion about the egalitarian achievements of post-secondary education and the debates over collective rather than individualistic values reflect a larger problem: the replication, in every corner of the education system, of the tension between egalitarian goals and the greater pressures to preserve inequalities through the operation of the schools.

The basic dilemma of vocational education has never been resolved: whether it provides greater opportunity by giving a chance for advancement to working class youth who would otherwise fail to continue in schools (the egalitarian claim), or whether it thwarts advancement by preventing some students from continuing to higher levels of eduction (the "cooling out" notion). If some of each outcome occurs, then there may be enough evidence to sustain both ideas, though the overall effect of vocational programs may be simply to reduce the variation of educational outcomes.[51] The dilemma of what vocational education really does remains the same, whether the content of vocational programs involves new technologies or old.

The Vocational Imperative

Vocational education for high-tech occupations provides genuine opportunities. These occupations require some real skills,[52] not just appropriate attitudes; the necessary skills include both "academic" components--especially knowledge of science and math, and some capacities for abstraction--as well as more "vocational" components related to manipulative skills and experience, a combination that suits vocational education in school settings perfectly. Post-secondary programs often train older students (rather than teenagers), students who are old enough to enter the "adult" labor market, students who have a better chance of knowing what they want to do and being well motivated. These programs also have the flexibility that has by now vanished from high schools and four-year institutions, and community colleges can adjust programs to suit the technical requirements of different occupations. The demand for middle-level high-tech occupations is real enough (even though demand has often been overstated), and the pay and working conditions of these jobs are certainly better than the semi-skilled assembler and service occupations lower in the occupational structure. Preparing students for these positions constitutes a job worth doing well--perhaps a job without the glamor and the status of preparing researchers on the frontiers of artificial intelligence, but still a job crucial to the well-being of firms and workers alike.

Still, at the very moment that high tech has come to national preoccupation, we can see the glimmers of potential problems, similar to those of vocational education in the past. One of these is the tendency towards exaggertion, overstating how many high-tech jobs will be available, and over-promising what vocational education can do to solve the country's problems.

In turn, this can lead all too easily to preparing too many students for too few jobs, or training students for jobs that need little preparation except brief on-the-job training. Another is the tendency to fall into too-specific training, under pressure to be "relevant" and to establish "partnerships". Particularly in the high-tech area, the tendency towards specific skills is inappropriate because the dominant complaint is that many students lack the general skills in science and math that are prerequisites for further learning, and because the pace of change more quickly makes specific skills obsolete. A final problem is a confusion about the egalitarian role of vocational education, generated by the dissonance between rhetoric and reality: at the same time that post-secondary schools claim for themselves the fulfillment of equal educational opportunity, they often operate to perpetuate old, familiar patterns of inequality.

The bandwagon effect in education is understandable, but its effects have always been ambiguous. Whenever it has appeared in the post-war period--in the Sputnik crisis of 1957, and the more recent crisis of confidence in the high school; in the discovery of compensatory education in the 1960s, and the school finance reforms of the 1970s; in the cries of undergraduates for "relevance" in the 1960s, and the cries for "relevance" (of a different sort) of undergraduates in the 1970s and 1980s; in the promise that schools can improve our competitiveness with Russia or with Japan, or contend with "social dynamite" in urban slums or with youth unemployent, or respond to the technological unemployment of the 1960s or the high-tech challenge of the 1980s---the results often have a similar cast. An excess of enthusiasm overstates the problem, underestimates the solutions, and leaves the essential structure of the schools unchanged after public attention has waned. The residues that remain--of which compensatory education is a good example--are often valuable, but just as often the fires of enthusiasm burn for nothing.

In the case of high tech vocational education, much larger forces drive the reactions of educators, students, businesses, and social commentators calling for a renewal of our "human resources". The vocational imperative is hard to resist: it gains support from students in search of jobs, businesses in search of trained workers, and educators in search of students, and it gives education an economic and social function larger than the training of students for a few vacancies. Beyond that, the power of vocationalism has been its ability to serve several contradictory roles of education simultaneously: the need to serve the interests of individual students while trying to address more collective goals; the duty to prepare students for a highly differentiated set of occupations while still passing on a common core of knowledge and values; the pressure to provide equality of educational opportunity within an unequal society where the pressures to reproduce inequality have been even greater; the need to use public resources in support of democratic goals, and the pressure from capital to use public resources for private ends; the need to serve simultaneously the "hand" and the "mind", the practical and the abstract, the vocational and the academic.

There is almost no constituency to resist vocationalism. Some educators try occasionally, complaining that the ability to reason is disappearing under the weight of vocational impediments, but they can be dismissed as academic and irrelevant. Some business people complain occasionally that their employees don't know the basics, but they often play a role in the use of educational credentials that is a part of vocationalism. The "back to basics" movement has periodically appeared in different forms, but this movement has concerned itself more with the "frills" of education and its egalitarian goals than with its vocational purposes. So too in the community colleges there have been opponents of its increasingly vocational role and proponents of a greater role for general education,[53] but they have been branded elitists, seekers of a false academic status, or barriers to growth; essentially they--like educators at all other levels of education--have no general conception of the role of schooling to offer in place of vocationalism.

The short-run appeal of vocationalism is irresistable, but the long-run consequences are poor: educational inflation, as students are driven to attend school longer to gain an advantage in the job market; the dilution of skill training and the degradation of learning, and their replacement with the search for credentials; heightened battles over access to education, while educational inequalities are replicated in new forms; unending battles between teachers and students, contributing to the sense of schools as unpleasant places; an increasingly irrational relationship between schooling and labor markets, even though vocationalism was always intended to establish a closer relationship between schooling and work. The power of vocationalism is a manifestation of the ability of capitalism to bend institutions to its end, but to do so in a way that is collectively irrational, in a way that makes these institutions less useful in the long run.

The emergence of new vocational challenges--like the appearance of new technologies--begins this cycle all over again. The outcome could be very different, and it still may be possible for post-secondary vocational education to avoid the pitfalls of the past. To do that, however, may require a different conception of schooling.

Footnotes

1. For a good review of the "optimist" and "pessimist" positions on technology, see Paul Attewell, "Microelectronics and Employment: A Review of the Debate", University of California, Santa Cruz, April 1983.

2. Henry Perkinson, *The Imperfect Panacea: American Faith in Education, 1865-1965*, (New York: Random House, 1968).

3. These figures are taken from the Vocational Educational Data System (VEDS), in National Center for Education Statistics, "Vocational Education Enrollment Remains Steady", December 1982. These data are difficult to compare with earlier enrollment data because of changes in methods of collection and definitions. For criticisms of the VEDS data, see Robert Barnes, "Ten Years of Federal Statistics on Vocational Education, U.S. Department of Education", April, 1984.

4. However, the evidence on returns to post-secondary vocational programs is still not extensive. Among other evaluations of secondary-level vocational education, see John Grasso and John Shea, *Vocational Education and Training: Impact on Youth*, (Berkeley: Carnegie Council on Policy Studies in Higher Education, 1979); Beatrice Reubens, "Education for *All* in High School?" in James O'Toole, ed., *Work and the Quality of Life*, (Cambridge: MIT Press, 1974); *The Vocational Education Study: The Final Report*, Vocational Education Study Publication No. 8, (Washington, D.C.: National Institute of Education, September 1981), Chapter 7; for some limited positive evidence, see Thomas Daymont and Russell Rumberger, "The Impact of High School Curriculum on the Earnings and Employability of Youth", in R. Taylor, H. Rosen, and F. Pratzner, eds., *Job Training for Youth* (Columbus: National Center for Research in Vocational Education, 1982). For evidence on post-secondary programs, see David Breneman and Susan Nelson, *Financing Community Colleges: An Economic Perspective*, (Washington, D.C.: The Brookings Institution, 1981); Larry Blair, Michael Finn, and Wayne Stevenson, "The Returns to the Associate Degrees for Technicians", *Journal of Human Resources* 16 (Summer 1981): 449-458; Harry Heinemann and Edward Sussna, "The Economic Benefits of a Community College Education", *Industrial Relations* 10 (October 1970): 345-354; Wellford Wilms, *Public and Proprietary Vocational Training: A Study of Effectiveness*, (Berkeley: Center for Research and Development in Higher Education, 1974); Wellford Wilms and Stephen Hansell, "The Dubious Promise of Post-Secondary Vocational Education: Its Payoff to Dropouts and Graduates in the U.S.A.", *International Journal of Educational Development* 2 (Spring 1982): 43-59; Fred Pincus, "The False Promise of Community Colleges: Class Conflict and Vocational Education", *Harvard Educational Review* 50, (August 1980): 332-361.

5. Data on enrollments come from the National Center for Educational Statistics, *Fall Enrollments in Higher Education*, various years.

6. On the shift to vocational programs and debates over academic versus vocational goals, see L. Stephen Zwerling, *Second Best: The Crisis of the Community College* (New York: McGraw Hill, 1976); Steven Brint and Jerome Karabel, "The Transformation of the Two-Year Colleges: From Liberal Arts to

Vocational Training", Huron Institute, Cambridge, September 1980; Pincus, op. cit.

7. Between 1965 and 1976 the proportion of two-year college students in vocational program increased from 13% to 50%; see American Association of Community and Junior Colleges, Types of Programs Offered in Two-Year Colleges (Washington, D.C.: AACJC). In 1978-1979, when total community college enrollments were 4,064,382, vocational enrollments in A.A. programs were 1,949,558 and enrollments in long-term adult programs--largely technical institutes--were 969,560 suggesting that as much as 72% of enrollments were vocational; see the National Center for Educational Statistics, The Condition of Vocational Education (Washington, D.C.: U.S. Government Printing Office, 1981), Table 3.2. These data are difficult to interpret because of ambiguity in what short-term and long-term adult programs include; thus, the VEDS data and the fall enrollment figures may not be compatible. At the same time, another 3,805,071 students were in "adult" vocational courses shorter than six months--many of these in non-degree programs within the community colleges. The shift toward vocational goals has also influenced degree recipients, as the data in Table 5 shows; in 1970-1971, 51% of all A.A. degrees and other awards below the B.A. level were in occupational curricula (rather than arts and sciences and other general program); by 1981-1982 this fraction had grown to 71%.

8. The parallels have been discussed in Martin Trow, "The Second Transformation of American Secondary Education", International Journal of Comparative Sociology 2 (1961): 144-165; Jerome Karabel, "Community Colleges and Social Stratification: Submerged Class Conflict in American Higher Education", Harvard Educational Review 42 (November 1972): 521-562; and Marvin Lazerson and W. Norton Grubb, American Education and Vocationalism: A Documentary History, 1870-1970 (New York: Teachers College Press, 1974).

9. James Mahoney, "Big Boom in Energy Programs", Community and Junior College Journal 52 (September 1982): 32-36.

10. Marion Rice, "College, Industry Join for Robotics Planning", Community and Junior College Journal 53 (April 1983) 47.

11. Mark Winter, "IVCC's Quantum Leap", Community and Junior College Journal 54 (November 1984) 43.

12. Dale Parnell, "Putting America Back to Work: Community, Technical, Junior Colleges Ready", Community and Junior College Journal 53 (September 1982): 12.

13. M. Ross Bagle, "College/Business Marriage: Sensible Response to Hard Times", Community and Junior College Journal 54 (November 1983): 15-17.

14. Richard Wilson and Dwight Davis, "Putting the Nation on Notice", Community and Junior College Journal 52 (April 1982): 6-8.

15. Don Garrison and Andrew Korin, "Toward a National Policy for Human Resource Development and Econonic Renewal", *Community and Junior College Journal* 52 (April 1982): 9-11.

16. On the "partnerships" with business and industry, see for example, Wilson and Davis, *op. cit.*; Bayle, *op. cit.*; Ronald Watchke, "Partnership Vital to High Technology", In *Community and Junior College Journal* 53, (December 1982/January 1983): 28-52; Catharine Warmbrod, Jon Persavick, and David L'Angelle, *Sharing Resources: Post-Secondary Education and Industry Cooperation* (Columbus, Ohio: National Center for Research in Vocational Education, 1981); Dale Parnell and Roger Yarrington, *Proven Partners: Business, Labor, and Community Colleges* (Washington, D.C.: AACJC, 1982); Harold Hodgkinson, "Establishing Alliances with Business and Industry", in George Vaughan and Associates, *Issues for Community College Leaders in a New Era* (San Francisco: Jossey-Bass, 1983).

17. On the conventional view, see Pincus, *op. cit.*; N.C. Harris and J.F. Grede, *Career Education in Community Colleges* (San Francisco: Jossey-Bass, 1977), especially Chapter 3; Fred Pincus, "Class Conflict and Community Colleges: Vocational Education During the Reagan Years", forthcoming, *Review and Proceedings of the Community College Humanities Association*.

18. C. R. Monroe, *Profile of the Community College* (San Francisco: Jossey-Bass, 1972), p. 82.

19. Attewell, *op. cit.*, provides a good synopsis of these positions.

20. The results in this section are preliminary findings from a larger study of the high technology sector in Texas and other states; see John Campbell and Susan Goodman, *High Technology Employment in Texas: A Labor Market Profile* (Austin: Bureau of Business Research, The University of Texas at Austin, in process). The definition of high-technology sectors they use is the "Massachusetts" definition, taken from *High Technology Employment in Massachusetts and Selected States* (Boston: Massachusetts Division of Employment Security, March 1981). The sectors considered high tech include those listed in Table 2 plus guided missles and space vehicles.

21. Of course, it is possible that the Texas experience is not typical of the rest of the country, particularly if Texas is now in an early "development" stage of its high-tech industry, rather than a more mature stage like California, Massachusetts, or North Carolina. On the other hand, one could argue that the Texas experience is more typical of the rest of the country, and that the experience of the "pioneers" is atypical. These arguments cannot be resolved without further empirical work.

22. Others who have made this argument include Henry Levin and Russell Rumberger, "The Educational Implications of High Technology", Project Report No. 83-A4, Institute for Research on Educational Finance and Governance, Stanford University, February 1983; Donald Tonaskovic-Devey and S. M. Miller, "Can High-Tech Provide the Jobs?", *Challenge*, May-June 1983; Richard Riche, Daniel

Hecker, and John Burgan, "High-Technology Today and Tomorrow: A Small Slice of the Employment Pie", Monthly Labor Review 106 (November 1983): 50-58.

23. There are three ways to examine students in community colleges: through N.C.E.S. data on fall enrollments, through the data on A.A. degrees and other formal awards, or through the VEDS data on enrollments on vocational programs. Most attention has focused on total enrollment, because the numbers of enrollees have become so high. The only data on enrollment by area of training comes from the VEDS sytem, which is unreliable and inconsistent; see Barnes, op. cit.. On the other hand, data on degrees has been consistently collected over a long period, and so these data are of much higher quality. In addition, there is an extraordinarily high drop-out rate from community colleges; enrollment patterns are not necessarily indicative of the real training that takes place, which may be better measured by degrees completed. Enrollment data may include a large number of students who enroll casually, without adequate information or concrete plans, and who are likely to drop out without acquiring significant skills. If students enter programs where occupational demand is weak and then drop out at a greater rate than students in programs where demand is strong, then patterns of completers will be more closely related to demand than are enrollment patterns. This is close to what we see in available data, where the relationship between enrollment and demand varies wildly while the relationship between degrees received and employment is much more regular. See W. Norton Grubb, "Occupational Demand and the Rise of Post-secondary Vocational Education", Institute for Research on Educational Finance and Governance, Stanford University, Report No. 83-A9, May 1983.

24. See Elizabeth Useem, "Education and High Technology Industry: The Case of Silicon Valley", University of Massachusetts at Boston, August 1981.

25. These figures use the moderate projections; see George Silvestri, John Lukosiewicz, and Marcus Einstein, "Occupational Employment Projections through 1995", Monthly Labor Review (November, 1983), Table 1.

26. Data on annual openings come from The National Industry-Occupation Employment Matrix 1970, 1978, and Project 1990, Vol. II, Bureau of Labor Statistics, Bulletin 2086, April 1981, Table 5.

27. Grubb, op. cit.

28. On cobweb cycles in professional occupations, see for example Richard Freeman, The Market for College-Trained Manpower (Cambridge: Harvard University Press, 1971).

29. On the lack of information available and of manpower foerecasting, see Harold Starr, "Vocational Education's Response to Skilled Industrial Worker Shortages", in Robert Taylor, Howard Rosen, and Frank Pratzner, eds., Responsiveness of Training Institutions to Changing Labor Market Demands (Columbus: National Center for Research in Vocational Education, 1983); W. Norton Grubb, Robert Glover, et al., The Persistent Dilemmas of Preparing

for Work: Occupational Training Programs in Texas (Austin: L.B.J. School of Public Affairs, 1983), Chapter 2.

The literature on higher education enrollments indicates that lower income (or lower SES) students are more sensitive to prices (tuition) and to unemployment rates and wages of unskilled workers (as measures of opportunity costs) than are higher income students. The evidence on responses to earnings differentials is much more sparse, though some results indicate that these responses are small. These findings suggest that community college students may react more to direct and opportunity costs than to the benefits of college in increasing earnings.

30. This example is cited in Pincus, op. cit. For a fuller examination of different explanations of rising community college enrollments and completions, see Grubb, op. cit.

31. Parnell, op. cit., p. 12.

32. Drake Campbell and D. M. Faircloth, "State Models for Economic Development", Community and Junior College Journal 52 (April 1982), 18-19.

33. On the history of these claims, see Lazerson and Grubb, op. cit.; W. Norton Grubb, "The Phoenix of Vocationalism: Hope Deferred is Hope Denied", New Directions in Education and Work 1 (Spring 1978).

34. Lester Thurow, "Death by a Thousand Cuts", New York Review of Books, December 17, 1981.

35. For reviews of the large literature on incentives for location, see Michael Barker (ed.), State Taxation Policy (Durham, North Carolina: Duke University Press, 1983); Advisory Commission on Intergovernmental Relations, Regional Growth: Interstate Tax Competition (Washington, D.C.: ACIR, March 1981); Roger Vaughan, The Urban Impacts of Federal Policies, Vol. 2: Economic Development, RAND Report R-2028-KF/RC, July 1977.

36. See the articles on education-business partnerships in footnote 16 above; see also Useem, op. cit, and Grubb, Glover, et al., op. cit.

37. Grubb, "The Phoenix of Vocationalism", op. cit.

38. For this criticism of customized training, see also Stuart Rosenfeld, "The New Shape-up: Schooling Workers to Stay in Line", The Progressive, April 1982.

39. Elizabeth Useem, "Education and High Technology Industry: The Case of Silicon Valley", August 1981, pp 15-16.

40. On the human capital model of specific and general training and the justifications for public funding, see Gary Becker, *Human Capital*, Second Edition (New York: National Bureau of Economic Research, 1975), Chapter II.

41. Paul Adler, "Rethinking the Skill Requirements of New Technologies", Harvard Business School, October 1983.

42. On the remedial function, see Arthur Cohen and Florence Brawer, *The American Community College* (San Francisco: Jossey-Bass, 1982), Chapter 9; Donald Barshis and Thomas Guskey, "Providing Remedial Education", in George Vaughan and Associates, *Issues for Community College Leaders in a New Era* (San Francisco: Jossey-Bass, 1983).

43. "AACJC President's Column: An Interview with Secretary Terrel Bell", *Community and Junior College Journal* 52 (December 1981/January 1982): 2-4.

44. William Vincent, "In Support of Open Admissions", *Community and Junior College Journal* 52 (Decdember 1981/January 1982): 12-14.

45. Seymour Eskow, "Putting Americans Back to Work: Phase II", *Community and Junior College Journal* 54 (November 1983): 12-14.

46. Karabel, *op. cit.*; Pincus, *op. cit.*

47. Robert G. Templin, Jr., "Keeping the Door Open for Disadvantaged Students", in George Vaughan and Associates, *Issues for Community College Leaders in a New Era* (San Francisco: Jossey-Bass, 1983).

48. On patterns of crowding by gender and race, see "Descriptive Study of the Distribution of Federal, State, and Local Funds for Vocational Education", Project on National Vocational Education Resources, University of California, Berkeley, September 1981, Chapter 7. These results may not be reliable because they are based on the VEDS data, criticized in Barnes, *op. cit.*.

49. The issue of equality of access has generated a debate within community college circles, between those "egalitarians" who want to maintain an open-door policy and the "elitists" who want to restrict admissions in order to increase the likelihood of completion, increase the overall equality of education, and maintain a balance between vocational and more academic courses. See the debate on "Transfer and Attrition" in the *Community and Junior College Journal* 52 (December 1981/Janury 1982): 17-23; William Shawl, "Are We Collegiate?", *Community and Junior College Journal* 53 (November 1982): 11.

50. Cohen and Brawer, *op. cit.*, p. 356.

51. That is, the existence of post-secondary programs may increase schooling for

some high-school gradutes who would otherwise not have continued past high school, and may decrease schooling for graduates who would otherwise have gone to four-year colleges and completed a B.A. if both these outcomes are substantial, then the variance of schooling falls without necessarily changing the average level of schooling. These outcomes have never been empirically examined, however.

52. Even this may not be uniformly true; for evidence that many employers value post-secondary education--even in technician programs--as socialization mechanisms rather than skill training see Wellford Wilms, "The Limited Utility of Vocational Education: California Employers' Views", Public Affairs Report 24 (August 1983), University of California at Berkeley.

53. On opposition to vocational goals, see Brint nd Karavel, op. cit. On the need for general education in community colleges, see Chester Case, "Reformulating General Education Programs", in George Vaughan and Associates, op. cit.

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Institute for Research on Educational Finance and Governance

SCHOOL OF EDUCATION STANFORD UNIVERSITY

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TECHNOLOGY AND THE REDESIGN OF WORK IN THE INSURANCE INDUSTRY

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Abstract

Driven by rapid changes in the financial environment, insurance companies are exploiting the capabilities of computer and information technologies to redesign jobs and reorganize work. Interviews at six major carriers indicate that the redesign of work varies widely within the industry, suggesting that there is considerable latitude in how the technology is utilized. Nevertheless, important trends can be discerned. It is already clear that automation is eliminating not only less-skilled clerical work, but also lower-level professional jobs as the more routine aspects of professional work are automated and folded into clerical jobs. This study examines the implications of these changes for employment levels, job skills, educational requirements and occupational mobility within the insurance industry.

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Financial corporations in the United States are undergoing a rapid transfromation as a result of the convergence of three powerful forces for change: high and volatile interest rates, rapid deregulation, and the diffusion and systematic application of computer and information technologies. The interaction of these forces is presenting financial corporations with the impetus to create new products and to alter the production process. While the consequences of these changes are just emerging, it is already apparent that major adjustments in the work force of the financial sector will be required.

The insurance industry is a case in point. Automation began in this industry around 1960 with the introduction of mainframe computers to handle customer billing and to provide management with detailed and timely accounting data. The carriers established data processing centers physically separated from other insurance operations. Employment of professional and clerical workers increased as these centers were staffed while jobs elsewhere in the firm were largely unaffected. The automation of routine underwriting and rating procedures, which began in the 1970s, also involved the computerization of discrete tasks at first. Some underwriting and rating functions were transformed, but initially automation meant the transfer of codified knowledge from a set of manuals to a computer program. The work process was largely unaffected and, despite the capabilities of the technology, an insurance application continued to pass routinely through five or more hands before policy was issued. Not until the financial environment was radically altered by the doubling of the inflation rate and the associated increase in interest rates in the 1970s did the industry begin to exploit the capabilities of computer and information technologies to develop new products and to experiment with the redesign of jobs and the reorganization of work. Driven by market forces and the capabilities of the new technologies, changes in the work process began in earnest in 1979.

This study investigates the nature of these changes and their implications for the insurance industry work force. As we shall show, the technological transformation of work in this industry has an impact on both the number and kinds of jobs in insurance. The greatest effect is on traditional clerical work. A study recently completd for the U.S. Department of Labor predicts that clerical employment in insurance will decline by at least 22 percent between 1980 and 2000, with most of the reduction occurring after 1990 (Roessner, 1984:26-27). Evidence currently available indicates that it is the women in traditional clerical jobs who face the greatest threat of loss of employment, routinization or "deskilling" of work, and decreased opportunities for occupational mobility (Feldberg and Glenn, 1983). However, changes in the work process as a result of the introduction of office automation technologies do not nearly parallel the fragmentation and deskilling of jobs that was characteristic of the mechanization of production in manufacturing. In contrast to earlier industrial automation, computer and information technologies do not eliminate skilled workers, nor do they reduce average skill levels across broad occupational groups. Instead, less skilled work--both clerical and professional--is being eliminated. Routine keyboarding is diminishing in importance. Skilled clerical work, however, is increasing and the remaining professional jobs require substantial amounts of formal training. The technology thus transforms and downgrades the more routine professional work into clerical tasks. At the same time, however, the skill level of clerical work is rising.

These findings are likely to have application far beyond the insurance industry. Nearly half the U.S. labor force works in an office. "Information workers"--managers, technical/professional, clerical, and sales personnel--currently comprise 53 percent of the labor force. Clerical workers, alone, represent nearly one-fifth of all workers. Office automation and other information technologies are permanently altering the nature of white collar and pink collar work. The insurance industry is on the cutting edge of these developments. The effects of technology on the nature of work in the insurance industry may very well signal the future direction of change in office work in the U.S. economy.

Approach of the Study

This investigation of adjustments in the insurance industry work force focuses on several important dimensions of change--the effect on the number of jobs, the distribution of occupations, the level of skills, the nature of clerical work, and the opportunities for upward mobility. Two subsidiary issues considered in this paper are the implications of these changes for women workers and for education.

The salient features of both the economic environment and the automation technologies are described in the next two sections. While this is a necessary beginning point for evaluating and forecasting the effects of automation on the work force, it is not sufficient; for the impact of new technology depends fundamentally on the way in which it is implemented.

For this reason, aggregate data available from the U.S. Department of Labor and a careful study of the specialized literatures on the various segments of the insurance industry as well as on office automation were supplemented with on-site visits and interviews at a small number of insurance carriers and agencies. Executives responsible for the implementation of new technology and for the design (or redesign) of jobs were interviewed. The Vice President for Human Resource Development was interviewed at every carrier and, where appropriate, The Vice President for Technical Systems was interviewed as well. At one carrier, in which automation of the sales force was the major technological priority, the Assistant Vice President for Personal Lines Marketing charged with developing the software and training the agents was also interviewd. Inteviews at agencies were conducted with the President of the agency as well as with agents and clerical staff.

In all, interviews were conducted at six carriers and two independent agencies. Two of the carriers are in the life/health segment of the industry, three are in the property/casualty segment, and one sells the personal lines (life, health, auto, homeowner's, accident) as well as group health. Four of the companies sell their products through independent agents, one has a captive agency sales force, and one is a direct writer using mail, television and other forms of direct solicitation to sell its products without a sales force. Assets at the carriers varied from $60 billion down to $0.2 billion. The sample, while small, is representative of the range of firms in the industry. These interviews, together with aggregate employment data and published descriptions of the technologies provide the basis for the remaining sections of the paper.

The Economic and Technological Forces for Change

Economic Environment

Interest rates doubled over the decade of the 1960s and nearly doubled again in the 1970s, reaching double digit levels by the end of the decade. Financial markets encountered difficulty performing well in these circumstances. Rising and increasingly volatile interest rates fueled a wave of financial innovation and deregulation as financial institutions sought to develop strategies for coping with the economic environment. "Financial institutions pushed out in all directions, and financial practices became highly flexible as financial deregulation proliferated both in fact and in formal law" (Sametz, 1984:8). Competition developed among large financial institutions whose functions and operations had been segregated by law since the 1930s.

Rising interest rates had a marked effect on the insurance industry, which depends primarily upon investment returns, not underwriting, for its overall profit. Traditionally, insurance carriers were major participants in the capital markets as they matched the maturities of their portfolios to expected claims. Inflation in the late 1970s turned yields on long terms assets negative, however, and encouraged insurance companies to find ways amoung regulatory standards on investment. Turbulence in financial markets increased the risks involved but also raised the possibility of large pay-offs for carriers whose investment managers outperformed the market. The large cash flow characteristic of the industry, and the possibility of high returns, attracted new entrants. Increased competition in all segments of the industry drove down the price of insurance. Average premiums per $1000 of coverage dropped sharply.

While the late 1970s were a period of high profits for property and casualty firms, following the initial adjustment to an inflationary regime, competition dangerously narrowed the margin between premium income and the cost of writing policies on commercial risks and also eroded the market share of some established carriers. Carriers turned to technology to reduce costs and to improve margins and regain market position.

Adjustment to inflation for carriers in the life and health segment of the industry was more difficult. Whole life, the industry's predominant product, combines insurance with a savings plan yielding a 4 to 6 percent return. With interest rates on competing savings instruments rising, the ability of life insurance products to attract savings declined. Sales of term insurane increased, but since term is much cheaper than whole life, premiums stagnated. Life insurance companies were under pressure to develop new products.

Variable annuities were developed during the 1960s. Variable life was proposed in 1972 and approved by the Security and Exchange Commission in 1976. Both are based on a portfolio of common stock and pay benefits that are not guaranteed but are contingent on the actual performance of the portfolio. Universal life, introduced in 1979, splits the premium and allows the consumer to decide how much goes to the death benefit and how much to savings. As with variable life, the premiums are placed in separate accounts and invested in securities whose returns are more sensitive to market rates of interest. Not until 1983, when carriers began providing their sales force with computers and software capable of calculating death benefits and cash value under a variety of interest rate projections and with the premium split in different ways, did these so-called "new wave" policies become significant. Universal life accounted for 18 percent of new premium income last year (Business Week, 25 June 1984:61). Life insurance companies have had to upgrade their computer systems and retrain their sales forces in order to sell these products. Moreover, competition from financial supermarkets not dependent on agents who collect commissions had created pressure on life insurance companies to use technology to upgrade the productivity of their traditional distribution system.

Office and Information Technologies

The production process in the insurance industry was rationalized decades before the introduction of office automation. Jobs were fragmented and functionally specialized, and paper wended its way around the office floor as surely as if it were on an assembly line. Introduction of the mainframe computer into the industry in the 1960s left this process largely untouched.

Computers at first were used to process routine or repetitive transactions. Mainly, they were used to keep track of and process all premium transactions. Claims disbursements were also automated early. In addition, the computer was used from the beginning to generate the numerous reports needed by the accounting department. Separate electronic data processing departments were establisehd. The resulting growth of computer specialists and operations research personnel contributed to the increase in professional employees during the 1960s while keypunch operators and computer operators increased the number of clerical workers.

In the 1970s the capabilities of the central computer were used to support the underwriting aspects of the insurance business. The technology allowed underwriters at field or central offices to accept applications. If accepted, the application would undergo overnight processing by the computer, which would also calculate the premium. The output would then be mailed from central processing to the field office or printed via remote printer. In addition to processing applications, the computer could generate activity reports for field offices.

To implement the technology, programmers translated the manual processing procedures into programs. Decision algorithms were incorporated into the programs, systematizing the decision-making process for underwriters. In the early period, underwriting rarely requires decisions that are not machine generated, and the computerization of underwriting for small or routine commercial risks is proceeding. At some carriers low level underwriting functions have been assigned to newly created clerical positions. Moreover, as underwriting jobs have been systematized, women have been hired into them.

Access to computer programs for underwriters is provided through telephone lines and CRTs. Initially, use of this technology required substantial clerical staff to code information and type attachments as well as to assemble and mail out the policy packages. Currently, policies are entered on-line as they are issued, and word processing handles the attachments. Routine keyboarding is declining.

Electronic typewriters and word-processing equipment spread rapidly in insurance offices in the 1970s. Electronic sorting of incoming mail, document control, electronic filing, and electronic mail are other important technologies in use in insurance. On-line processing of policies and optical character recognition techniques adopted over the last decade have reduced the need to code information onto worksheets and to keypunch it into the computer. Substantial savings in labor time in routine clerical work has already been achieved.

The next stage of office automation is integrated information processing, in which components that do word and data processing are linked through high speed communications networks. These systems are used to support both clerical and decision-making functions. Important problems have slowed the adoption of this technology in insurance offices. These include high cost, the expectation of future improvements, and unresolved questions of access to and responsibility for central files.

Software is currently being developed to provide the on-line data and information services essential for middle and senior management and for professional staff. There are two aspects to the required technology--an appropriate data base and data base technology, and terminals or small computers capable of transparent interface with the central computer, other terminals and a variety of peripherals. Data base management systems are now in the process of development and implementation. Since the batch oriented accounting support systems already in place do not lend themselves readily to the demands of the decision support system, firms face difficult and expensive choices. The technology is expected to improve the performance of managers, but it has run into difficulty being accepted. The issue is not reluctance to use a keyboard per se, but more general complaints about access methodology. Managers complain that with existing keyboard menu-based systems, the personal time and effort required to get into the system are too great in terms of what can be gotten out of it. For the present, professional support staff are increasing as some companies establish separate programming staff responsive to the needs of managers.

Cost-effective software services are being made available to property claim departments. These include computerization of automobile and property claim estimates as well as damageability and management report information. Computerization does not yet extend much beyond auto though other personal lines and worker's compensation claims are being automated. Computerization automatically captures all estimate information without duplicate keypunching. Data can then be summarized into management reports and used to improve the efficiency of the claims management operation. Linking the claims data base to other data bases will also allow insurers to predict claim frequency and to estimate loss ratios.

Carriers are actively engaged in automating the sales force. Although some agencies have used minicomputers for several years, the cost proved difficult for most to justify. Originally it was believed that the expense of computerizing agencies would not be warranted without interface between agents and carriers. In the last year, however, the carriers have recognized the importance of computerization in improving the productivity of agents. Moreover, new wave life policies can't be marketed without the high speed calculating capability of the computer. As a result, some carriers are currently helping their high volume agents obtain sophisticated equipment and specialized software, either providing them outright or subsidizing their purchase. The computer is used mainly to prepare sales proposals or to expand and focus marketing efforts. A few carriers have established interface with a small number of high volume agents, enabling them to underwrite, rate and issue policies directly. Independent agencies that do not produce a high enough volume of business to warrant computerization by the carrier have established a common network to interface with agencies that have this capability.

Technologically advanced firms have targeted the distribution system and the management function for cost-cutting via technology during the remainder of the decade. Interest in networks that allow otherwise noncompatible machines to interact is high, but implementation of the paperless electronic office is a low priority for most carriers.

Changing Jobs, Skills, and Career Ladders

An important insight that has emerged after several years of experience with office technologies is that the technologies used to automate clerical, underwriting and processing functions differ fundamentally from older industrial technologies. The management of office automation must likewise differ. The logic of scientific management in a factory setting meant that work was rationalized and fragmented as it was automated. Productivity increased, but in the process worker skills were devalued, tasks became repetitive, and a sense of responsibility for the company's product was diminished. When automation was first introduced into an office environment, the same logic prevailed. In the insurance industry, where work had long since been fragmented, computerization was applied to discrete tasks. Skill levels tended to decline and the automated tasks were routine and repetitive.

As experience with office automation increases, however, it appears that in contrast to earlier factory automation computer and communication technologies are often most effective in reducing costs when control, communication and decision making are decentralized and when hierarchic organization and the functional specialization of tasks are reduced. Recent applications of these technologies have involved the elimination of both low skill clerical and routine technical and professional jobs, and the creation of new, multiactivity, skilled clerical positions to handle these functions. A less common alternative is to broaden the agent's job by folding routine underwriting and rating functions into it and providing for the printing and issuing of policies at the point of sale. The result has been a significant reduction in unit labor requirements and an increase in the average skill levels of the remaining clerical, sales and professional work force. The following examples illustrate these changes.

In the property and casualty segment of the industry, competition has driven down premiums on small or unexceptional commercial risks--condominiums, stores, commercial auto, worker's compensation--despite rising costs, substantilly reducing the profitability of these lines. One major insurer has developed a strategy that reduces the costs of processing an application and improves the efficiency of its distribution network. The carrier is developing computer programs that assist in underwriting and rating of these commercial lines, and agents are being trained to use these programs. The carrier is providing its highest volume and most professional agents (about 10 percent of its sales force) with intelligent terminals linked to its central computer. The terminals are also linked to printers capable of issuing a policy at the point of sale. When the procedures are fully implemented, all clerical processing will be eliminated for sales generated by these agents. Policy typist, rater, and underwriter's assistant--jobs which provided career paths from clerical to lower level professional jobs as underwriters--are disappearing. In fact, the lower level jobs as insurance professionals are rapidly declining as well.

Jobs for the most skilled underwriters remain, but the jobs have changed. Skilled underwriters no longer manage risk, they manage agents. They oversee the agent's "book of business"--assessing the agent's success at underwriting, offering advice, developing customer profiles, focusing marketing efforts, assuring the professionalism of the agency--and encouraging the agent to do a volume of business that warrants the carrier's investment. A few of the displaced clerical workers are being retrained and given basic programming and trouble-shooting skills in order to provide technical support to agents using computer terminals. But most of the traditional clerical and professional functions in accepting or rejecting an application and in issuing a policy will be performed by the agent.

A very different example is provided by the carrier that sells personal lines insurance, standardized products that can be mass marketed without agents through direct mail and television solicitation. Direct writers, as they are called, are the most profitable and most rapidly growing carriers. New companies have entered this market, undercutting existing firms and causing wide swings in market share. One established company, which experienced a sudden drop in market share in 1980 had previously automated mail handling and filing, thus eliminating nearly all unskilled clerical jobs. Policies were entered on-line and the system could handle inquiries for current information about coverage immediately. The work process was extremely fragmented, however, to the extent that customer inquiries were answered by different people with different job titles depending on whether they came by mail or telephone. The first step taken when business declined was to integrate some of the tasks to facilitate reductions in staff. This first round of integration made no use of computer technology. But by 1983, information technologies had been used to create multiactivity jobs in the operations area that were highly integrated. Since the company's products were standardized, underwriting and rating functions were entirely computerized and the jobs eliminated. Instead of these positions, a new highly skilled clerical position has been designed. Customer service representatives handle sales, access the computer program that assesses risk, access the rating program, explain rating procedures to customers, answer customer questions and respond to complaints by telephone or mail.

Thus the company responded to the loss of business and the need to "skinny down" by a change in job design. Success is apparent in the fact that by 1983 the company was again doing its 1979 volume of business, but with half the number of employees.

Job redesign has included both the integration of tasks into multidimensional jobs and the elimination of the lowest level clerical and less skilled professional jobs. The resulting configuration of jobs varies from firm to firm, but in every case job categories have become more abruptly segmented while the avenues of mobility between them have been sharply reduced. Many of the newly created jobs are characterized by few opportunities for the exercise of judgment and increased managerial control over the pace and content of work as compared with the profesional jobs they replace. Yet, these very jobs are less fragmented, less centralized, involve considerable training, and often require significant knowledge of the product.

The effects of automation on skills in the insurance industry vary from carrier to carrier. It can be said, however, that the new techniques do not eliminate skilled workers nor do they reduce required skills to the barest minimum. The clerical jobs that remain fall into two categories--routine keyboarding (text or data entry, accessing of underwriting and rating programs) and skilled activities (customer service representative, claims representative, secretary). Routine keyboarding is decreasing in importance as office technology continues to advance and as work is reorganized so that sales are entered online. Skilled clerical work continues to increase, however, as the more routine aspects of professional work are automated and become part of the clerical function. The requirements for skilled clerical work are high general literacy skills, good verbal communications skills and an aptitude for arithmetic, but no specific business or insurance skills. The remaining professional jobs--exceptions or special risks underwriters, lawyers, electronic data processing professionals, actuaries, financial managers--require years of formal training in insurance or other disciplines. As a result of the automation of underwriting and claims estimating for standardized insurance products, career ladders from skilled clerical to insurance professional positions have been eliminated. The gap between the skills of clerical workers and those of professionals has widened despite the elimination of unskilled clerical work such as coding and sorting mail and much filing, and the reduction of routine keyboarding. Skill requirements for clerical workers have increased at the same time that the jobs have become overwhelmingly dead-end.

The effect has been to eliminate a range of middle level jobs within this industry and to close off avenues of upward mobility for those in clerical occupations. Male clerical workers always had opportunities for advancement to insurance professional and managerial positions. But until the 1970s women were prevented from advancing by the sex segregation of occupations--underwriters, managers and even clerical supervisors and office managers were usually men. Today, partly as the result of successful affirmative action suits against several carriers, sex is a much less effective barrier to mobility. Now it appears that newly-opened avenues of advancement from clerical work to professional jobs are being blocked by new structural barriers--the elimination of less skilled professional positions. While the more routine kinds of underwriting are being computerized, credentials for entry into commercial lines and special risk underwriting are increasing. They often include a college degree plus the requirement that the employee obtain professional certification. The gap between the skills required in skilled clerical work and those required in the remaining insurance professional and professional staff positions appears to be unbridgeable in the context of how work is currently being organized. Avenues of mobility which have only recently opened up for women clerical workers are already disappearing.

Thus the introduction of microprocessor-based technologies and the dramatic redesign of jobs is altering the distribution of occupations in insurance. Office automation has wiped out thousands of jobs for low-skilled clerical workers, created new jobs for skilled clerical workers, and eliminated many professional jobs that comprised the middle of the occupational distribution--and that used to constitute the rungs of a career ladder by which clerical workers could climb up into more highly skilled professional jobs. Declines in unskilled clerical jobs have limited the entry-level job opportunities for minority and working class women. What is more, the opportunities for advancement by even the more highly skilled clerical workers are being closed. The bottom and the middle of the occupational distribution are both shrinking in the insurance industry.

Changes in Employment and Occupations

The introduction of automation in the 1960s, characterized by the use of mainframe computers, did not discourage employment growth at carriers. Property and casualty firms experienced average annual employment growth of 2.7 percent through the decade (Table 1). Job growth was paced by rapid increases in the numbers of professional, technical, and clerical workers (Table 2).

Not until the 1970s--when the costs of mail-sorting and word-processing equipment dropped, optical character recognition technology became available, and software to automate most personal lines rating and underwriting was developed--did automation slow the growth of employment. The slowdown was most apparent in the life and health segment of the industry which deals entirely in personal lines. Employment growth in this segment averaged 0.9 percent per year. In contrast, employment growth at property and casualty carriers, whose business is dominated by commercial risks that are only now being automated, averaged 3.2 percent per year between 1970 and 1978. It slowed to 1.7 percent in the last years of the decade as automation of office clerical and professional work accelerated.

While employment of raters and underwriters is not reported in the National Industry-Occupation Matrix, their numbers appear to have declined. This may have been offset to some extent between 1970 and 1978 by the 120 percent increase in computer operators, a category that includes operators of peripheral equipment such as CRTs (Table 2). The spread of word-processing equipment and electronic dictating machines is reflected in declines in the absolute numbers of typists and stenographers. The effects of increased on-line processing can be seen in decreases in the numbers of keypunch operators and file clerks. Data for the 1978-1981 period are available, though they are not strictly comparable with figures cited in Table 2 (U.S. Department of Labor, n.d.). The trends reported in these data are consistent with those reported for the earlier period. Most clerical categories show a relative decline (i.e., in employment share), while some occupations registered absolute declines. These include manual bookkeeping clerks, correspondence clerks, file clerks and raters as well as typists and stenographers.

Two recent studies look ahead to the years 1990 and 2000 and examine the effect of office automation on employment (Roessner, 11984; Leontief and Duchin, 1984). Roessner is concerned with the effects of automation on clerical employment in insurance and banking. His study identifies several "breakthrough" technologies with the potential to reshape clerical work, examines their impact on a matrix of clerical tasks and functions, and concludes that the most likely time path for clerical employment in insurance is "flat clerical employment through about 1990, then a decline in employment by 2000 to 61 percent of the 1980 level, or from 924,000 to 568,000 employees....At minimum, we foresee absolute reductions in clerical employment of 22% in insurance...by 2000" (Roessner, 1984:26-27).

Leontief and Duchin examine the automation of office operations in business enterprises generally. They consider two scenarios, the more modest of which assumes slower adoption of computer-based work stations and integrated electronic systems. Since integrated electronic systems ("paperless offices") are expected to be slow in penetrating the insurance industry in this decade, this scenario is of greater interest. In this scenario Leontief and Duchin conclude that the number of stenographers, typists and secretaries required to produce the ouput of 1977 with the technology of 1990 will be 85 percent of the 1977 number. For office machine operators it will be 45 percent and for other clerical workers it will be 88 percent. By 2000 the proportions will fall to 76, 15 and 74 percent respectively. While labor requirements per unit of output are falling, the labor force and demand for output are both growing over time. Weighing reductions in unit labor requirements against growth in production, Leontief and Duchin conclude that office employment in the U.S. economy will continue to grow, though they do not report results for particular industries such as insurance.

The interviews I conducted with insurance executives suggest that Roesnner's conclusion that there will be substantial drops in insurance industry employment is correct. For example, the carrier described earlier had already eliminated most mail handling and filing jobs through automation of these functions when it faced a sudden $23 million dollar decline in business. In 1979, the year before it lost this major contract, it employed approximately 5,000 people. By 1981, the company was down to 2,700 people. Today, the company does a dollar volume of business that exceeds the 1979 level with only 3,000 employees, an employment drop of 40 percent.

Roessner's analysis and findings, however, are focused too narrowly on traditional clerical employment. Cost-cutting strategies at insurance carriers rely heavily on eliminating professional jobs by standardizing more routine professional functions and turning them into skilled clerical work. Thus, some part of the decline in traditional clerical jobs which he identifies may be offset by the creation of new clerical functions. In addition, many carriers expect a shake-out in insurance agencies in which only the larger, more professional ones survive. They anticipate a leaner sales force with fewer agents writing a larger volume of business as automation proceeds.

Finally, the carriers anticipate slow growth or a decline in management ranks. Excessive growth in management and supervisory pesonnel characterized both the life and health and property and casualty segments of the industry between 1970 and 1978. Reasons for this vary. Some firms, locked into compensation schemes geared to low inflation rates, promoted employees to raise salaries when inflation exploded. Others quietly used "title inflation" to achieve affirmative action promotion goals. Some firms rewarded their professional staff with managerial designations. By 1982 many carriers had succeeded in breaking this promotion cycle. In addition, most carriers set increases in white collar productivity and the elimination of redundant management ranks as high priorities. The Leontief and Duchin study estimates that increases in productivity of managers as a result of automation, even in the more modest scenario, will allow the 1977 volume of work to be done with 99 percent of the 1977 managers in 1990 and 88 percent by 2000.

Implications for Women and for Education

Shifts in the occupational distribution in the insurance industry have important implications for employment opportunities for women. Women comprise virtually 100 percent of the employees in clerical occupations in which employment has declined. Because of the high turnover rates in clerical jobs in insurance, reductions in staff were accomplished largely through attrition. Nevertheless, traditional clerical jobs for which non-college bound women frequently train while in high school declined by a total of 28,556 positions between 1970 and 1978. At the same time, skilled clerical positions are being penetrated by women and new skilled clerical jobs are being created. Thus, women insurance adjustors, examiners and investigators (occupations which are classified as clerical) were 9 percent of the total in 1971, and 58 percent of the total in 1981 (U.S. Department of Labor, 1982). Employment in these occupations increased more than 58,000 between 1970 and 1978, while percent female nearly doubled. As a result, the number of women holding such jobs increased by approximatley 56,000. Thus the feminization of insurance adjustor, examiner, and investigator occupations more than offset the decliens in traditionally female clerical jobs before 1978. These jobs will be affected, however, as the automation of claims procedures progresses.

As a result of both the technological dynamic and the penetration by women of male occupations, the skills required of women clerical workers are rising. Insurance companies have adopted several strategies for hiring women with the appropriate skills. These include moving the work from central cities to small towns, suburbs and rural areas where the work force is mostly white and pay for women is lower. A second strategy firms have followed is to hire college graduates for career clerical positions. While clerical work does not require any specific skills learned in college, including computer courses since the level of computer literacy required in clerical jobs is easily mastered, college graduates are hired to ensure that general literacy and problem-solving requirements of the jobs will be met.

Minority women have only recently penetrated clerical work and are still found mainly in the less skilled clerical jobs. Thus automation is eliminating precisely those jobs in which black women are present in significant numbers. The movement of clerical work to small towns and suburbs and the increased hiring of college educated women for these jobs also limits opportunities for black women. These developments have a similar negative impact on employment possibilities for less educated urban white working class women as well.

The issue of upward mobility is also an important consideration. As argued above, job categories have become more segmented. The gap between skilled clerical and professional employees has grown larger, and jobs that constituted the career path from clerical to professional work have largely been eliminated. This does not mean that professional, technical, sales and lower level management jobs are likely to become entirely male again. On the contrary, jobs for college educated women professionals, and to a lesser extent managers, continue to open up. Women increased from 10 percent of insurance agents, brokers and underwriters in 1962 to 12 percent in 1971 and 24 percent in 1981 (U.S. Department of Labor, 1982). This is reflected in the employment growth of women in the agencies/brokers segment of the industry (Table 3), though most of these jobs of course are clerical. Non-clerical jobs, it appears, will continue to desegregate. The on-going recruitment of women as computer programmers, marketing managers, and underwriters is seen by the carriers as obviating the need for promotion from clerical to professional or managerial ranks to provide women with opportunities.

Men continue to dominate those departments from which the carriers choose their top managers and executives--finance, marketing, investment, and actuary. But women have been entering professional and lower managerial ranks and can be expected to continue doing so. Some of the specialized occupations within these categories may become majority female since educated women can be hired more cheaply than similarly qualified men. The result could be lower pay and lower status in those jobs, with the work devalued because it is done by women.

The occupational structure for women in the insurance industry is becoming increasingly two-tiered. It has been observed that the occupational hierarchy is not as gender segregated as in the past, but occupational stratification occurs increasingly along class and race lines (Baran and Teegarden, 1983). Educated white women with the appropriate credentials and class background enter the upper tier as jobs there continue to desegregate. The vast majority of women in insurance, however, are relegated to totally segregated clerical jobs. Technology is eliminating the least skilled of these, but literate clerical workers, especially if they're white, will find their situation essentially unchanged.

Implications for Education

The combined effects of technology and changes in the economy are placing new demands on the U.S. educational system. As exemplified by the insurance industry, office automation has raised skill requirements for clerical workers. Employers have made it clear that they want high schools to provide a strong foundation in reading, math, written and verbal communication and problem-solving skills. Computer literacy is viewed as a less pressing reuirement since the computer skills required by non-specialists can be acquired through company training by workers who have reading and problem-solving capabilities.

Thus automation is blurring the distinction between vocational or commercial education and academic education in secondary schools as new technology increases the importance of reading and analytical skills for clerical workers. With job content changing as automation progresses employers want, and workers require, broad occupational preparation as well as specific technology-related vocational skills. A broad education is essential because it increases individual career choices, provides a foundation for learning new skills, and allows an individual to adjust effectively to a job change or a change in the work environment. These are qualities which workers need in order to deal with likely future changes in skill requirements in office industries.

Specific vocational skills related to current office technologies which are useful for business students are word processing, data processing, electronic mail and electronic records management. It should be noted, however, that the insurance industry has a long history of providing company and industry sponsored training programs to teach specific vocational skills (including word processing, telephone speaking skills, even BASIC) as well as insurance concepts and procedures to workers who require them. As unskilled clerical and routine keyboarding jobs decline, the proportion of workers requiring such training is increasing. Carriers are stepping up their training and retraining programs, and industry-wide educational organizations are responding by developing new courses. Employers' primary concern, therefore, is with hiring workers who will be successful in these training and elducational programs and for whom training costs can be kept to a minimum.

Women need college degrees to enter professional jobs now that the jobs that constituted internal career ladders are declining.

Opportunities for college education need to be made more generally available. Inner city high schools need the resources to prepare students for entrance into degree programs. Otherwise the desegregation of occupations by gender will mask an equally invidious exclusion of inner city women, especially black women, from these jobs.

The need for increased emphasis on training in mathematics for women is also apparent. Arithmetic as well as problem solving and analytical skills are necessary in both clerical and professional jobs. Moreover, women need advanced training in mathematics in order to enter top professions (for example, actuary, operations research or financial manager in insurance) from which the upper ranks of corporate management are often filled.

By shifting the occupational distribution toward skilled clerical and highly trained professional jobs, office automation is challenging the educational system to design instructional programs that provide a sound foundation in basic skills for all students and that prepare high school graduates for a lifetime of continuing education, either in college, other post-secondary schools or industry-based instructional programs. The educational establishment is also being asked to develop programs to meet the newly emerging lifelong need for education for those in the labor force.

Conclusions

Automation is changing job opportunities in the insurance industry. It has already eliminated thousands of traditional clerical jobs--for file clerks, data entry clerks, typists, bookkeepers, stenographers and mail handlers. The diffusion of existing office and information technologies are expected to cause further declines in these occupations and to reduce the employment of key punch operators, office machine operators and word processing personnel as well. Recent studies of clerical work suggest that by 2000 it will be possible to produce the 1977 volume of output with less than 75 percent of 1977 clerical employment. One study predicts an absolute reduction in clerical employment in insurance of at least 22 percent, with a 39 percent reduction most likely. The executives I interviewed expect substantial reductions in unit labor requirements and actual declines in employment during the 1980s except for those firms able to increase market share. For the industry as a whole, declines in the absolute level of employment in line with Roessner's projections are anticipated.

In addition, the work process itself is being transformed by technology. Although the redesign of jobs varies widely among insurance firms, the elimination of less skilled clerical jobs and the reorganization and downgrading of more routine professional work are characteristic of the on-going changes. New skilled clerical jobs such as underwriter's assistant and customer service representative, as well as the upgrading of existing positions such as claims representative, have emerged as a result of automation. These jobs offer less in terms of pay, prestige, decision-making and advancement than the professional jobs they replace. But they also represent an upgrading of skill requirements and, to a lesser extent of pay, for clerical work. Skill levels in clerical jobs, and in the remaining professional jobs as well are rising.

Opportunities for upward mobility for clerical workers who want to move from skilled clerical to professional positions, however, have been sharply curtailed. The insurance industry has only recently begun to establish career clerical positions--skilled but dead-end clerical jobs.

This has happened as the routine aspects of professional work have been automated and folded into clerical jobs, and lower level professional jobs have been eliminated. These jobs used to comprise a career ladder for cléricl workers. Declines in unskilled clerical jobs have limited the entry-level job opportunities for minority and working class women while opportunities for advancement by even skilled clerical workers are also being closed.

In these circumstances, the role of the educational system in preparing women, who are 61 percent of this industry's current labor force and who comprise nearly 100 percent of the workers in traditional clerical jobs most affected by automation, for the remaining employment opportunities is a key one. Women must be college educated in order to compete for the remaining professional jobs. They must be literate with good communication and problem-solving skills to compete for skilled clerical jobs. Failure to improve the quality of inner city schools will close off clerical employment for minority and white working class women.

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TABLE 1

Insurance Industry Employment,[a] Selected Years

Year (annual average)	Property/ Casualty	Life/ Health	Agencies/ Brokers	Total Insurance
1960	288,700	502,500	207,200	1,008,600
1970	365,800	619,500	288,000	1,273,300
1978	460,600	661,400	392,800	1,514,800
1980	490,500	680,500	454,100	1,625,100
1981	484,400	679,600	457,500	1,621,500
1982	472,100	680,900	475,500	1,628,500

Percent Change in Employment (annual average)

Period	Property/ Casualty	Life/ Health	Agencies/ Brokers	Total Insurance
1960-1970	2.7	2.3	3.9	2.6
1970-1978	3.2	0.9	4.6	2.4
1978-1981	1.7	0.9	5.5	2.5
1980-1982	-1.9	0.0	2.9	0.1

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[a] Does not include insurance industry labor force employed in real estate offices, stock brokerage houses, etc. (approximately 6 percent of the industry labor force, but increasing).

Source: U.S. Department of Labor, Employment and Earnings, United States, 1909-1978; U.S. Department of Labor, Employment and Earnings, Table B-2, March issue, various years.

TABLE 2

Insurance Industry Employment by Selected Occupations: 1960, 1970, 1978 and Projected 1990

Occupation	1960 Number	 Percent	1970 Number	 Percent	1978 Number	 Percent	1990 Number	 Percen
MANAGERS/OFFICERS	144,000	13.3	160,011	11.8	194,200	12.1	289,663	14.8
PROF/TECH WORKERS	34,700	3.2	77,773	5.8	96,468	6.0	108,487	5.5
Accountant			24,188	1.8	28,805	1.8	39,762	2.0
Systems Analyst			3,833	0.3	5,514	0.3	5,514	0.3
Programmer			11,078	0.8	12,388	0.8	11,580	0.6
CLERICAL WORKERS	512,000	47.4	675,427	50.0	730,242	45.4	869,847	44.3
Computer Operator			9,751	0.7	21,374	1.3	20,640	1.1
Keypunch Operator			24,026	1.8	18,763	1.2	12,278	0.6
Statistical Clerk			37,799	2.8	40,214	2.5	40,153	2.1
Bookkeeper			48,099	3.6	44,549	2.8	36,611	1.9
Adjustor, Examiner			99,082	7.3	157,354	9.8	227,506	11.6
File Clerk			34,185	2.5	27,440	1.7	31,021	1.6
Mail Handler			9,334	0.7	8,332	0.5	5,947	0.3
Secretary			178,161	13.2	192,853	12.0	275,433	14.0
Typist			92,472	6.9	81,661	5.1	95,306	4.9
Clerical Supervisor			15,134	1.1	16,739	1.0	16,702	0.9
SALES	363,000	33.6	404,846	30.0	555,408	34.5	663,667	33.8
Agents, Brokers			403,700	29.9	554,083	34.4	662,828	33.8
OTHER	29,650	2.7	32,844	2.5	31,488	1.9	30,682	1.6

Source: U.S. Department of Labor, Bureau of Labor Statistics: Tomorrow's Manpower Needs, Vol. II, "National Trends and Outlook: Industry Employment and Occupational Structure," Bulletin #1606 (1969); The National Industry-Occupation Employment Matrix, 1970, 1978 and Projected 1990, Vol. I, Bulletin #2086 (1981).

TABLE 3

Employment of Women in the Insurance Industry, Selected Years
(in thousands)

Year (annual average)	Property/Casualty		Life/Health		Agencies/Brokers		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1960	165.8	57.4	252.7	50.3	112.2	54.1	530.7	52.6
1970	207.8	56.8	314.7	50.8	158.8	55.1	681.3	53.5
1978	283.4	61.5	371.6	56.2	239.1	60.9	894.1	59.0
1980	308.8	63.0	396.9	58.3	282.1	62.1	987.8	60.8
1982	294.0	62.1	401.3	58.9	301.4	63.4	996.7	61.2

Source: U.S. Department of Labor, Employment and Earnings, United States, 1909-1978; U.S. Department of Labor, Employment and Earnings, Tables B-2 and B-3, March issue, various years.

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THE POTENTIAL IMPACT OF TECHNOLOGY ON THE SKILL REQUIREMENTS OF FUTURE JOBS

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Abstract

This paper assesses the potential impact of technology on the skill requirements of future jobs. The paper first explores some of the theoretical and methodological issues surrounding the topic of skill requirements. Then it examines the impact of past technologies on skill requirements. Changes in the skill requirements of jobs result from changes in the skill requirements of individual occupations and from shifts in the composition of jobs in the economy. In the past, technology tended to reduce the skill requirements of jobs, while the changing composition of jobs favored more skilled occupations. In the future, technology will continue to lower the skill requirements of many occupations, while future job shifts will not favor more skilled occupations. Some of the implications of this future scenario are discussed.

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Technological change and global competition make it imperative to equip students in public schools with skills that go beyond the 'basics.' For productive participation in a society that depends ever more heavily on technology, students will need more than minimum competence in reading, writing, mathematics, science, reasoning, the use of computers, and other areas.

Task Force on Education for Economic Growth
Education Commission of the States

There is a widespread belief in the United States that the application of new technologies in the workplace is raising the average skill requirements of jobs. In order to better prepare students for the demands of their future work roles, a number of influential commissions have called for sweeping improvements in the nation's schools. They caution that a failure to meet this challenge will not only limit students' opportunities in the future labor market, but it will threaten the U.S. competitive position in the growing world marketplace.

New technological innovations, spurred by the revolution in microelectronics, are appearing with increasing frequency in the marketplace. New generation microcomputers are leading the way. As these machines become smaller, cheaper, and more powerful, they are being used in a wide variety of jobs throughout the economy. Some experts believe that half of all American workers will be using some sort of computer device in the their jobs by the end of the decade (Giuliamo 1982, p. 152). But will the increased use of these more sophisticated technologies require workers with more sophisticated skills?

While most people believe that workers will need increased skills to deal with these new technologies, two kinds of evidence challenge these beliefs. First, studies of recent applications reveal that in many cases new technologies can actually lower the skills required in jobs, not raise them. Second, technology affects the average skill requirements of jobs through its impact on the distribution of jobs in the economy as well as the skills of individual occupations. Recent employment forecasts suggest that future job growth will favor low-level clerical and service occupations. So even if technology raises the skill requirements of some occupations, it could still lower average skill requirements of jobs in the economy by favoring employment growth in low-skilled occupations.

The impact of technology on skill requirements of jobs in the future may be quite different than its impact in the past. Older technologies greatly reduced the physical demands of work. Employment for laborers, for example, declined from 30 percent of the work force in 1900 to less than 6 percent in 1970. During the same period employment in more skilled professional and technical jobs increased from 4 percent to 14 percent (U.S. Bureau of the Census 1975, Table D 182-232). Future technologies will further reduce the physical demands of work, but they will also be able to reduce the mental demands of work. New information technologies not only can store and process large amounts of information, they can exercise judgement through complicated, decision programs. As these technologies become more complex and sophisticated, they will be capable of performing more complex and sophisticated mental tasks.

Whether technology lowers or raises skill requirements of jobs in the future has important ramifications for education and the economy. If technology does reduce the skill requirements of jobs, then current efforts to improve education and upgrade the skills of future workers may prove to be dysfunctional. A growing number of students may find that their increased educational competencies are not required in the workplace. Already, a sizeable portion of the American workforce has more education than their current jobs require (Rumberger 1984a). Raising educational attainments at a time of decreasing or even steady skill requirements could further increase this imbalance. And recent evidence suggests there could be a sizeable cost to this imbalance through reduced worker effort and productivity (Tsang 1984). Increased educational attainments in the face of reduced skill requirements could actually impair economic performance in the future.

At the moment, however, it remains unclear whether technology will raise or lower the average skill requirements of future jobs. Research cannot predict what the impact of future technologies will be. Studies of past technologies are suggestive. But in general, little empirical research has addressed the issue of skill requirements. Little theoretical discussion has been devoted to this topic as well.

The purpose of this paper is to assess the potential impact of technology on the skill requirements of future jobs. The first section of the paper will examine some of the theoretical and methodological issues surrounding the topic of skill requirements and the influence of technology. The next section will review some empirical studies that have attempted to assess the impact of past technologies on skill requirements of jobs. The following section will then speculate on the likely impact of new technologies on future job skills. The final section of the paper discusses some of the implications of this future scenario.

The Study of Skill Requirements

Scholars from a variety of academic disciplines, including economics, sociology, and industrial psychology, have long been interested in the study of skills. Most of this attention, however, has focused on the skills that workers bring into their jobs, measured by education and training, rather than the skill requirements of jobs themselves. In fact, skill requirements associated with jobs are not recognized or treated in neoclassical economic theory. As a result, literature that examines the impact of technology on the skill requirements of jobs is rather limited and generally falls outside the neoclassical paradigm.

Theoretical Issues

Human capital theory, the principle paradigm in neoclassical economics, recognizes skills only as characteristics of individuals and generally analyzes them indirectly, through their association with education. As Becker, one of the principle architects of this view, points out: "education has little direct effect on earnings; it operates primarily indirectly through the effect on knowledge and skills" (Becker 1964, p. 86). In this view, education either develops skills that are valued in the workplace, or simply identifies persons with these skills (Spence 1973; Taubman and Wales 1974).

The reason that skills are only associated with individuals is found in the tenets of neoclassical theory. According to this view, skills, in the form of human capital, are treated like physical capital. In order to maximize profits, firms hire each factor of production until the value of its marginal product equals the cost of hiring it, given available techniques of production and market prices. The wage paid to each category of skilled labor, therefore, equals the value of its productivity to the firm. It is assumed that the skills possessed by workers are fully utilized by the firm since employers can readily shift factors of production to respond to changing factor prices or production techniques.

In reality, of course, employers may be unable or unwilling to fully utilize the skills of their workers. Interestingly, neoclassical economists acknowledge that physical capital may not be fully utilized in all instances and have developed the concept of capacity utilization to measure this discrepancy. But they do not acknowledge that, in a similar manner, human capital may not be fully utilized as well. Yet organizational theorists and industrial psychologists have long argued that a variety of factors may prevent the full utilization of workers' skills (Rumberger 1983). These factors include the way work is organized in the firm, particularly the designation of tasks into jobs.

Neoclassical theory also offers little insight into how technology will affect the demand for skills. Technology is generally treated as an exogenous factor in the production process. So little attention has been given to the issue of substitution between human and physical capital. Some view physical and human capital as complementary: more complex skills enable workers to better use more complex technologies in the firm (Nelson and Phelps 1966). Yet little empirical research exists to support these notions.

The concept of skills as characteristics of jobs and the impact of technology on skill requirements have been treated in other economic paradigms and by other academic disciplines.

It is the notion of jobs that gives rise to the concept of skill requirements. Jobs identify sets of tasks that individuals perform in the workplace. Scholars from a variety of disciplines have studied a number of characteristics associated with jobs. Sociologists have concentrated on occupational status or prestige (e.g., Spaeth 1979; Granovetter 1982). Some economists have examined occupational differences in earnings as well as nonpecuniary rewards associated with jobs (Eckaus 1973; Duncan 1976). Industrial psychologists have identified a wide number of physical and social characteristics of jobs that affect productivity and behavior in the firm (e.g., Vroom 1964).

One important characteristic of every job is the set of skills that workers require to perform the tasks associated with it. This concept recognizes the distinction between the skills that workers bring into their jobs and the skills that their jobs require. The two may not be the same. Employers can raise the hiring requirements of a job because of changes in the available supply of job applicants without changing the tasks or duties associated with the job. They may prefer workers with more education simply because it reduces the costs of training them in the specific skills that their jobs require (Thurow 1975). And because the allocation of workers to jobs depends on available supplies of workers and jobs, workers may actually possess more skills than their jobs require. Moreover, if the distributions of skills associated with workers and jobs fail to move in the same direction, then discrepancies between these two measures of skills could increase over time.

It is generally assumed that the skill requirements of jobs have increased over time simply because new technologies have helped to transform the economic base of the country, creating new, more skilled jobs in the process. The earlier transformation of the U.S. economy from agriculture to manufacturing—spurred by technical developments in power generation, communications, transportation, and industrial machinery-created new jobs for skilled production and professional workers. The more recent transformation from manufacturing to service, brought about by developments in electronics, communications, and transportation, have created new jobs for professional and technical workers. To economists, these technical developments have increased the demand for education and both have contributed to past economic growth in the United States (Denison 1979).

One of the most compelling challenges to the prevailing view that skill requirements have increased over time has been offered by Harry Braverman (1974). Braverman argues that employers attempt to fragment work tasks into simpler components, thereby deskilling jobs, for two important reasons: to lower their costs and to better control the work process. The economic incentive for lowering skills was first recognized by Adam Smith in the Wealth of Nations and later refined by Charles Babbage more than 150 years ago:

> That the master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided (quoted in Braverman 1974, pp. 79-80).

Braverman argues that "...Babbage's principle eventually becomes the underlying force governing all forms of work in capitalist society, no matter in what setting or at what hierarchical level" (Braverman 1974, pp. 81-82). The principle architect of scientific management, Frederick Taylor, also recognized the economic gains from fragmenting tasks into less skilled components and using "men who are of smaller calibre and attainments, and who are therefore cheaper than those under the old system" (quoted in Shaiken forthcoming, p. 19).

Employers long have recognized and responded to this economic incentive. Henry Ford saw the value of using low-wage, low-skilled workers to perform some of the tasks associated with automobile assembly more than 80 years ago (Gartman 1979, p. 196). Today builders employ less skilled workers at lower wages to prefabricate portions of homes in order to reduce labor costs (San Francisco Examiner 1982).

Technology can further this process of fragmentation. After work is fragmented into discrete tasks, some of the tasks can be performed by machine. Henry Ford first fragmented the tasks associated with automobile manufacturing into an assembly line process, and then later mechanized certain tasks, such as the movement of cars along the line (Gartman 1979, p. 200). As technology becomes more sophisticated, machines can perform a greater number and more complex tasks. In modern automobile plants, robots weld and paint cars as well as perform a variety of other tasks.

But whether technology reduces skills depends on what tasks are mechanized and what new tasks are created by the use of new machines. Many people believe that machines are used primarily to perform the least skilled tasks and that to use more complex machines workers require more complex skills. Yet employers can achieve greater cost savings by mechanizing complex tasks performed by high-wage labor than by mechanizing simpler tasks performed by low-wage labor. In other words, General Motors has more incentive to replace high-wage automobile workers with robots than McDonalds has to replace workers who earn minimum wages.

Similarly, the easier new machines are to operate, the lower the wages employers have to pay someone to use them. Manufacturers therefore deliberately design machines that require less skill to operate (Shaiken forthcoming, Chapter 3). And by using such machines, employers can reduce their labor costs. The management of the National Broadcasting Company, for example, recently argued to their workers' union that the new computer-driven videotape machines are so sophisticated that they can be operated by lower-wage, nonunion workers (Business Week 1984a, p. 71).

Technology also affects the skill requirements of jobs through its influence on the number and types of jobs available in the economy. The development of new technologies creates new jobs in the firms that manufacture them as well as new jobs in firms where they are employed. Technology also eliminates jobs. But what is the net impact of this process? Are more jobs created by technology than eliminated? Are the jobs created generally more skilled than the jobs destroyed? Although current research fails to provide definitive answers to these questions (Rumberger 1984b), evidence reviewed below does suggest some answers.

Measuring Skill Requirements

In order to determine the impact of technology on the skill requirements of jobs, it is necessary to develop measures of skill requirements. But the nature of job skills makes this task very difficult: skills vary widely by level and type, they change over time, and they can vary widely between firms.

Researchers have identified a number of different skills and personal characteristics that contribute to effective work performance. These include cognitive skills, physical or motor skills, communication skills, attitudes, and personality traits (Peterson and Bownas 1982). Some skills are general and can be applied to a wide variety of work settings. Other skills are specific in that they can only be applied in a limited number of work settings or firms (Becker 1964). Skills also vary by level. Higher-order, complex skills require more time to learn than the mastery of simpler, lower-level skills.

Since a wide variety of skills are used in the workplace, it is difficult to develop appropriate measures that can identify each type. To identify the skills of workers, researchers frequently rely on one or two proxy measures, such as education or years of experience, that fail to capture either qualitative or quantitative differences in skills. Educational credentials, for example, reveal little about how much or what kind of learning took place in school and hence what skills were developed. The skill requirements of jobs are even more difficult to measure. Not only is it important to identify the various kinds and levels of requisite skills, the requirements need to be assessed independently of the skills possessed by the workers holding those jobs.

Another difficulty in trying to measure skills is that they can change over time. The introduction of new technologies can create new jobs and change the skill requirements of existing jobs. The more rapidly these changes come about, the more skill requirements are likely to change. This presents a serious problem in assessing skill requirements of new technologies since they are being developed and applied with greater frequency throughout the current labor market.

Finally, skill requirements can vary widely according to the organization of firms (Levin 1982). Even seemingly standard jobs, such as computer programmer or machinist, can have different duties in different firms. The impact of technology on job skill requirements will also depend on the way work is organized in response to these technologies. All firms may not respond in the same way.

These characteristics of skills make research on skill requirements of jobs exceedingly difficult to perform. Just the large number of different jobs that exist makes a comprehensive assessment of skill requirements for the overall economy almost impossible. In the United States, the Department of Labor does attempt such an assessment through The Dictionary of Occupational Titles. Conducting field assessments in a sample of firms every 10 to 12 years, the Labor Department measures a number of cognitive skills that workers require to perform their jobs. The latest survey was published in 1977 and covers approximately 20,000 jobs (U.S. Department of Labor 1977). These surveys have been used to measure the distribution of skill requirements in the U.S. economy and changes in skill requirements over time (Spenner 1979; Rumberger 1981a). But the data are difficult to use and do not overcome all the difficulties outlined above (Miller et al. 1980).

Although assessing the skill requirements of jobs and the impact of technology on them is extremely difficult at an aggregate level, research on particular occupations and industries has addressed these issues. These studies, which are reviewed below, provide some insight into the possible impact of new technologies on the future skill requirements of jobs.

The Past Impact of Technology

Past technologies have altered the tasks and skill requirements in a wide range of jobs throughout the U.S. economy. Technology has also helped to alter the distribution of jobs in the economy. Have these two impacts raised or lowered the average skill requirements of jobs?

The Skill Requirements of Jobs

Studies of a wide range of occupations suggest that past technologies have often reduced the skill requirements of jobs in both the factory and the office. These studies also reveal that the application of technologies takes place in conjunction with the process of job fragmentation: jobs are fragmented into a series of tasks and then some of the tasks are performed by machine. Together these two processes have eliminated jobs, increased managerial control, and lowered skill requirements.

The printing industry is one area where deskilling has taken place. As the printing industry developed, the work associated with the printing process was fragmented into a number of highly specialized components, including typesetting, makeup, photoengraving, and presswork. New technologies first began to displace many of the physical tasks associated with this work and then many of the mental tasks. In the typesetting operation, for example, linotype machines and later teletypesetting machines removed the physical work involved in setting metal type. Then the computer removed the mental skills associated with word hyphenation and line justification. Finally, phototypesetting eliminated the use of metal type altogether and, along with computer word processing, completely destroyed the traditional craft of typesetting. Other technological advances have reduced the skill and labor requirements in other areas of the printing process (Zimbalist 1979; Wallace and Kalleberg 1982).

Skill requirements of jobs were also lowered in factories. During the 1950s American factories began to automate many aspects of production. Union leaders worried that many jobs would be lost and that unemployment would rise. Others worried that automation would eliminate low-skilled employment opportunities. James Bright, a professor at the Harvard Business School, examined the effects of automation on the skill requirements of jobs in a wide variety of manufacturing firms. Contrary to widespread opinion, Bright observed that the skill requirements of jobs first increased with the introduction of new technologies, but later decreased as these technologies were refined (Figure 1):

> Automated machinery requires less operator skill, or at least not any more skill, after certain levels of mechanization are passed. It appears as though the average worker can more quickly and easily master new and different jobs where highly automatic machinery provides the skill, effort, and control required. Furthermore, some "key" skilled jobs, currently requiring long experience and training, are reduced to easily learned machine-tending jobs (Bright 1958, pp. 176-177).

One important technological development in the factory is the numerical controlled (NC) machine tool. NC machine tools redefine the tasks and hence the skill requirements of machinists. With traditional machines tools, machinists would determine how to machine a part and then produce it. With NC, the planning or "how to" function was separated from the execution function. Programmers would determine how to produce a part through a series of numerical machine codes, so machinists would simply have to feed the machine and respond to any problems that arose. As a result, the "skill" of the machinist was transferred to the machine. More recent developments have now automated the tasks of programming, further reducing the skills required in machining. Although NC has had less affect on the practice of machining than one might expect because of both technical and social difficulties, it still provides an important illustration of how employers and machine designers have attempted to lower skills and reduce costs on the factory floor (Shaiken forthcoming, Chapter 4).

Deskilling has taken place in the office as well as the factory. As large offices evolved in the late nineteenth century, office work was divided along hierarchical lines, with relatively few managerial workers performing the mental work and a large cadre of clerical workers performing the manual tasks (Glenn and Feldberg 1977). Clerical work was fragmented into a large number of specialized occupations—typist, switchboard operator, receptionist, file clerk, duplicating machine operator--with low-wage workers performing the least-skilled jobs. Office machines furthered the process of fragmentation. New word processing equipment made typing pools more cost-effective and allowed managers to better control the "paper production" process. Machines were also able to displace some of the more skilled clerical jobs. Dictating machines, for example, have largely eliminated jobs for skilled stenographers.

The computer field provides one final illustration of skill displacement. Early computer programmers had to know as much about the capabilities and applications of hardware as the software or coding language. As computers became larger and more powerful, programming was fragmented into a number of discrete occupations requiring widely different skills: systems analysts designed large-scale software, programmers wrote the instructions, and keypunch operators coded the information. Increased memory capacity and other technical improvements allowed the development of more sophisticated languages and "canned" packages that further simplified the job of programming (Kraft 1977; Greenbaum 1979). Recent developments have reduced the labor requirements associated with computers as well: new generation microcomputers and "user-friendly" software require neither programmers nor operators.

These case studies suggest that, at least in some areas of work, past technologies have been used to lower skill requirements and reduce wage costs. Studies done at a more aggregate level suggest little change in the average skill requirements of jobs (Spenner 1979; Rumberger 1981a). Overall this evidence challenges the widely held view that technology tends to raise skill requirements.

The Composition of Jobs

Fragmentation and technology affect the distribution of skills within industries by creating new occupations and altering the skill requirements of existing ones. But the distribution of skills in the overall economy also depends on the distribution of employment among industries. Since different industries have different occupational mixes, employment shifts among industries can significantly alter the skill requirements of jobs in the economy independently of skill changes that occur within industries. Two factors have altered the distribution of employment among industries over this century: 1) changes in the demand for goods and services; and 2) differences in productivity and productivity growth among industries.

Consumer spending patterns have shifted towards increased purchase of services. In 1940, for example, 39 percent of personal consumption expenditures went for services, whereas in 1980, 47 percent went for services (U.S. Council of Economic Advisors 1984, Table B-2). Other components of demand—investment, imports and exports, and government purchases—have also shifted. As a result, some sectors of the economy, primarily those in the services-producing area, have grown much faster than others (Table 1).

Differences in productivity and productivity growth rates have also affected employment patterns. In manufacturing, for example, economic output increased 213 percent between 1947 and 1981, the same rate of growth as the economy overall (Table 1). Yet employment only increased 30 percent because of improvements in productivity. In contrast, employment growth in services equaled the growth in economic output from that sector because productivity remained constant over this period. In agriculture, economic output increased 65 percent over this period, while employment declined by 60 percent. Different productivity levels among industries also mean that two industries with similar economic growth rates will produce different employment growth rates.

Because the composition of jobs varies so widely among industries, changing patterns of employment among industries have greatly altered the composition of jobs in the economy. Employment growth among major occupation groups for 20 year intervals since the beginning of the century are displayed in Table 2. These data document a number of important trends. First, they show the decline in agricultural employment that has occurred throughout this century. Second, they show the growth of employment within service occupations. Third, they show the growing importance of white-collar employment.

It is difficult to infer from these data whether employment shifts have favored higher or lower skilled occupations. The reason is that occupational titles reveal little about actual skill requirements of jobs. Many people suppose that the shift from blue-collar to white-collar employment suggests an increase in the average skill requirements of jobs. Yet jobs in the office have been subject to the same process of fragmentation and deskilling as jobs in the factory. So the labels "white-collar" and "blue-collar" actually reveal little about job content or requisite job skills. Moreover, the skills of particular jobs within major occupation groups vary quite widely (Rumberger 1981a, Table 2).

Despite these limitations, employment shifts, at least in recent years, do appear to have favored more skilled occupations. In the 1960-80 period, professional and technical jobs increased by 8.5 million, compared to an increase of 2.1 million clerical jobs. This contrasts with earlier periods where clerical employment increased more than professional and technical employment. The decline in employment for laborers and farm workers (many of whom are laborers) also suggests a general upgrading of the skill requirements of jobs in the economy.

While the case studies reviewed above suggest that at least some jobs in the economy have been deskilled, employment shifts suggest a general upgrading of jobs. What has been the net increase of these two factors?

One recent study suggests that the distribution of skills in the U.S. economy have actually narrowed as a result of these two factors. Rumberger (1981a), using data from the two most recent editions of The Dictionary of Occupational Titles, examined changes in the distribution of skills in the U.S. economy between 1960 and 1976. He found that changes in the distribution of jobs in the economy did, indeed, favor more skilled occupations. Yet changes in the skill requirements of individual jobs tended to reduce skills at the high end as well as the low end of the distribution. The net result of these changes was to increase skill requirements in the middle and upper-middle range of the skill distribution and reduce skill requirements at the upper and lower ends of the distribution (Table 3).

The Future Impact of Technology

The skill requirements of jobs in the future economy will also depend on changes in the skill requirements of jobs and on shifts in the composition of jobs in the economy. Technology will influence both.

The Skill Requirements of Jobs

There is little doubt that technology will have a widespread and profound impact on work in the future. More and more people will be using computers in their future jobs. Computers have already changed the way work is performed in virtually every sector of the economy, from agriculture to design (Scientific American 1982). As new, more sophisticated applications are developed, they will be applied to more and more jobs.

But how the increased use of computers and other sophisticated devices affects the skill requirements of jobs will depend on two factors: 1) the technical capabilities of the technologies, and 2) how the technologies are actually employed in the workplace. The technical capabilities, in turn, will depend on the number and range of tasks that new machines will be able to perform. Past technologies were limited to performing relatively simple physical and mental tasks. In some cases the technology failed to perform as well as expected and thus had less affect on skills than originally anticipated (Shaiken forthcoming, Chapter 4). But future technologies, based on incredible advances in microelectronics, are likely to be more reliable and will be able to perform a greater variety of more complex physical and mental tasks. As technology advances, more tasks will be able to be performed by machines and, as a result, more worker skills displaced. Several recent technologies illustrate the potential skill displacement of modern machines.

The modern cash register provides one simple illustration. Cashiers at McDonalds simply press the keys on the machine corresponding to each item. The machine recalls the prices of the items, calculates the total bill, including the tax, and determines the amount of change after the cashier enters the denomination of the customer's bill. Thus cashiers no longer have to be able to add and subtract because the machine performs these functions. New scanning devices in supermarkets only require cashiers to pass items over a scanner that reads the barcode on the product, records the price, and even keeps a record of all sales for reordering purposes. These advances have reduced the requisite skills for cashiers.

Current word processors reduce the need for letter-perfect typing skills because corrections can be made easily on the screen before a hard copy is produced. New systems can now correct spelling mistakes and even grammatical errors. Thus the need for traditional secretarial skills is reduced. At the same time, little more skill is needed to use these machines than traditional typewriters and the skills are easily learned. As word processing software has become more sophisticated, it has become even easier to use or more "user-friendly." Apple, the manufacturers of the new-generation Lisa and MacIntosh computers, claim that they can teach first-time users to perform a series of office functions after 30 minutes of instruction.

These devices represent the current state of technology. But the power of the computer promises more sweeping and much more sophisticated applications in the future. The center of this development work is in the area of artificial intelligence or simply AI. Artificial intelligence is concerned with the development of computer systems that can mimic the functions of the human mind, including sensing, speaking, storing and retrieving information, reasoning, and even learning. Although computers have a long way to go before approaching the capabilities of humans, researchers in AI have long recognized this potential. As one AI expert recently said: "Anything--anything--humans can do, artificial intelligence can do" (San Jose Mercury 1984).

That potential has already been demonstrated in a number of new applications called expert systems. Expert systems are computer programs that perform like human experts: they take information on current conditions, draw on a vast reservoir of knowledge, and make judgments based on this information and knowledge. Thus they are able to perform high-level, complex mental tasks that traditionally have been the domain of the most desirable and highly-paid workers in the economy: professional workers. Systems are now being developed in a wide range of professional areas, from medical diagnosis to design. Recent demonstrations have already proved how well they can rival the expertise of humans.

A geology expert system developed by SRI International provides one illustration. The system was programmed using information obtained from interviews with nine expert geologists on the processes they follow in locating mineral deposits in the field. In a recent demonstration, the system was fed information on conditions in one area.

> After considering all the answers, the computer was able to pinpoint the ore in a small, unexplored area that was ringed by earlier borings and mines. SRI's expert system succeeded where humans failed because its capability to consider mind-boggling amounts of data far exceeded that of any flesh-and-blood expert (Business Week 1984b, 55).

Another area where expert systems have great potential is in the medical field. Here the knowledge base is large and constantly changing. Already the Chinese have developed such a system as a way of utilizing the vast knowledge accumulated from centuries of medical practice. One computer in Nanjing, China was programmed from the expertise of 3 prominent herbalists who were all in their 80s. After a doctor's assistant measures the patient's symptoms, the information is entered into the machine. The machine then diagnoses the illness and recommends treatment.

> What "Doc Computer" lacks in bedside manner, it more that compensates for in speed and effectiveness. In three years of practice two afternoons weekly, the machine has treated 6000 patients with what is reported to be a higher rate of recovery than ordinary physicians boast. The fee usually falls under $1 per visit, including the cost of medicinal herbs (San Francisco Examiner 1984).

Expert systems and other new technologies will make it easier for workers to access and process large amounts of information. Yet workers will not have to have more sophisticated skills to use these systems. To the contrary, the more sophisticated the technology, the easier it is to use. Just as new automobiles and stereos that incorporate sophisticated technologies require less not more skills to use, future devices in the workplace based on sophisticated technologies will require fewer skills to operate.

Whether the skill requirements of jobs rise or fall due to the increased use of new technologies will not only depend on the technical capabilities of these new machines, but how these machines are actually used in the workplace. If these technologies are used to further fragment work tasks, with machines increasingly performing more complex tasks, then skill requirements will likely decline. If, however, new machines enable workers to perform a wider range of tasks and they are given this latitude in using them, then skill requirements as well as productivity could actually increase (Levin 1984; Shaiken forthcoming, Chapter 6). Recent studies of the banking and insurance industries suggests that some recent technologies have been used in this way

(Appelbaum 1984; Adler forthcoming; Baron and Teegarden forthcoming). But future impacts will depend on the outcome of particular applications that result from both technical and social considerations.

The Composition of Jobs

While future technologies will be able to perform more complex mental tasks and reduce the skills required to use them, the skill requirements of jobs in the future will also depend on the composition of jobs in the economy. And that will depend on what jobs are displaced by machines and what sectors of the economy will grow in the future.

Just as employers have an economic incentive to fragment jobs into component parts in order to reduce labor costs, they also have an economic incentive to automate jobs that pay the highest wages. Thus expert systems and other sophisticated technologies are more likely to eliminate more skilled, high-salary jobs than less skilled, low-salary ones. The increased use of these devices will create new jobs in industries where they are manufactured and new jobs related to their use and maintenance. But recent employment projections for the U.S. suggest that few new jobs will be created in these areas.

Consider employment in firms where new technologies are developed and produced. Recent employment data from the U.S. Bureau of Labor Statistics indicate that only about 6 percent of the American workforce is currently employed in "high-tech" industries, based on a definition that covers 28 detailed industries from computer manufacturing to data processing services. These projections also suggest that only about 8 percent of the new jobs expected between 1982 and 1995 will be in these firms (Rumberger and Levin 1984, Table 3).

Employment projections do indicate that many jobs related to the use and maintenance of new technical devices, particularly computers, will experience rapid employment increases over this period. Jobs for computer service technicians, computer programmers, and computer operators are projected to be among the fastest growing jobs in the U.S. over the next decade. Yet because these jobs currently employ relatively few people, these rapid growth rates will generate few new jobs, especially in comparison with more traditional clerical and service occupations. For instance, there will be more new jobs for janitors between 1982 and 1995--779,000--then there will be new jobs for computer service technicians, computer programmers, computer systems analysts, and computer operators combined (Rumberger and Levin 1984, Table 4)!

The increased use of new technologies is not expected to directly generate many new jobs in the U.S. economy in the near future. Rather future job growth will continue to be in more traditional areas where jobs were produced in the past. A comparison of projected employment growth within major occupation groups for the period 1982 to 1995 shows similar patterns to employment growth in the previous two decades (Table 3): employment in farming occupations will continue to decline, while the majority of new jobs will be in professional, clerical, and service occupations. Comparisons among the three periods reveal some surprising trends. For example, professional and technical occupations are expected to generate a smaller proportion of new jobs in the 1980s and 1990s (20 percent) than in either the 1960s (25 percent) or the 1970s (23 percent). At the other extreme, a small but increasing proportion of future jobs will be for laborers. Managerial employment is also expected to slow after increasing rapidly in the 1970s.

These projections, while by no means conclusive, suggest that the future economy in the United States is unlikely to shift toward an increasing proportion of high-skilled occupations. This contrasts with the situation in previous periods where employment growth tended to shift the average skill requirements of jobs upward. Since the increased use of advanced technologies could also reduce the skill requirements of many existing jobs, these two factors have the potential to lower the average skill requirements of future jobs.

Summary and Conclusions

Technology will have a widespread and profound impact on work in the future. One of those impacts will be to alter the skills that workers will require to perform their jobs. But will workers require more or fewer skills to perform their jobs in the future?

Although more detailed studies on the impact of new technologies on the skill requirements of jobs have yet to be done, existing studies suggest that technologies often reduce the skills workers require to perform their jobs. Moreover, employers have an economic incentive to eliminate high-skilled, high-wage jobs in order to cut labor costs. As further advances in micro-electronics lower the prices and increase the processing capabilities of future machines, they will be used to replace workers with more sophisticated skills. Current expert systems have already demonstrated the mental capabilities of new generation computers. And because the machines are so sophisticated, they make it easier for workers to use them.

Of course new jobs will be created for workers who design and build these new sophisticated devices. But recent employment projections indicate that relatively few new jobs will be created either in firms where these devices are built or in occupations related to their use (Rumberger and Levin 1984). Rather future job growth will continue to be dominated by retail trade and service employment, where there are a higher concentration of low-skill, low-wage jobs than in other sectors of the economy sector (Rumberger 1984b, Table 3). The net effect of these two trends will be to reduce the average skill requirements of jobs in the future job market.

One implication of this scenario is that current efforts to raise educational standards in the U.S. could produce a future generation of dissatisfied and unproductive workers. Recent evidence suggests that workers who have more education than their jobs require not only become dissatisfied, they are less productive (Rumberger 1981b, Chapter 5). A current imbalance between the education level of workers and the skill requirements of their jobs could explain some of the recent slowdown in productivity growth in the U.S. (Tsang 1984). This imbalance could easily increase in the future, threatening the ability of the U.S. to compete in the world marketplace.

Technology not only affects the skill requirements of jobs, but also the control of work. As Braverman points out, fragmenting job tasks enables employers to better control the work process as well as lower labor costs. Technology can work in the same way. Along with the development of new information technologies have come new ways for employers to monitor the performance of their workers. New systems that greatly increase the productivity of telephone operators and insurance workers have already been developed, but the rigid monitoring has brought widespread complaints as well (New York Times 1983; Wall Street Journal 1983). Unions have now raised technology as an important bargaining issue.

The impact of technology on the skill requirements of jobs in the future is in no way predetermined. It will depend, in part, on the technologies that are developed. But it will also depend on how those technologies are used in the workplace. Although past technologies have often reduced the skills of workers and lessened their control over the work process, that does not have to be the case. In some firms, technology has been used to increase the discretion of workers, broaden the tasks they perform, and raise the skill requirements of their jobs (Levin 1982, 1984). Technology holds the promise of making work easier in the future and reducing the amount of work people have to perform in order to enjoy a high standard of living. The future challenge is to insure the promise of technology is achieved and the threat it poses is avoided.

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Table 1

Economic Output, Employment, and Output Per Worker by Major Industry, 1947 and 1981

Industry Group	Economic Output[a]			Employment[b]			Output/Worker[c]	
	1947	1981	Change (%)	1947	1981	Change (%)	1947	1981
Agriculture	26.3	43.4	65	7.9	3.4	-60	3,329	12,765
Goods-producing								
Mining	10.8	22.3	106	1.0	1.1	18	11,309	19,700
Construction	22.9	52.0	127	2.0	4.2	110	11,450	12,381
Manufacturing	114.9	359.2	213	15.5	20.2	30	7,413	12,832
Services-producing								
Trans./Utilities	42.3	142.1	236	4.2	5.2	24	10,071	27,327
Trade	75.9	250.4	230	9.0	20.6	129	8,433	12,155
Fin./Insur./R.E.	54.7	243.6	345	1.7	5.3	212	32,176	45,962
Services	55.9	196.7	252	5.0	18.6	272	11,118	10,576
Government	68.7	178.1	159	5.5	16.0	191	12,491	11,131
TOTAL[d]	467.8	1477.2	216	57.0	100.4	76	8,207	14,713

[a] Billions of 1972 dollars.

[b] Millions of persons. Agriculture and TOTAL show all employed workers. Other categories show wage and salary workers only.

[c] 1972 dollars.

[d] Economic output represented by gross domestic product.

Source: U.S. Council of Economic Advisors, Economic Report of the President (Washington, D.C.: U.S. Government Printing Office, 1984), Tables B-11, B-29, B-37.

Table 2

Employment Growth by Major Occupation Group, 1900 to 1980

(Millions of Jobs)

Major Occupation Group	1900-20	1920-40	1940-60	1960-80
White-collar	5.4	5.6	11.2	23.4
Professional and technical	1.0	1.6	3.5	8.5
Managers	1.1	1.0	1.7	4.1
Clerical	2.5	1.6	4.6	8.7
Sales	.8	1.4	1.4	2.1
Blue-collar	6.6	3.6	5.0	7.4
Craft	2.4	.7	3.0	4.2
Operatives	2.9	2.9	3.3	2.2
Laborers	1.3	---	-1.3	1.0
Service workers	.7	2.7	1.5	5.2
Farm workers	.5	-2.4	-4.9	-2.4

Note: Data for the 1900 to 1960 periods cover the experienced civilian labor force, 14 years old and over. Data for the 1960-80 period covers the employed population, 16 years old and over. Data not strictly comparable because of changes in the classification of occupations.

Sources: U.S. Bureau of the Census, Historical Statistics of the United States, Colonial Times to 1970, Bicentenial Edition, Part 1 (Washington, D.C.: U.S. Government Printing Office, 1975), Table D 127-141; U.S. Bureau of the Census, Statistical Abstract of the United States: 1984, 104th Edition (Washington, D.C.: U.S. Government Printing Office, 1983), Table 693.

Table 3

Employment Growth by Major Occupation Group, 1960 to 1995

(Percentage distribution)

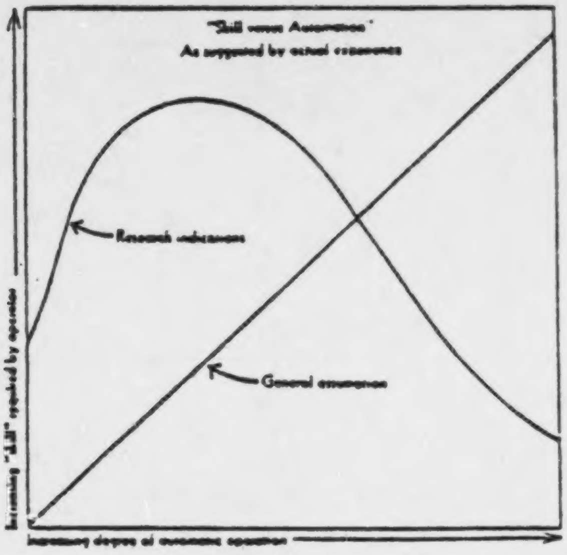
Major Occupation Group	1960-70	1970-80	1982-95
White-collar			
Professional and technical	25	23	20
Managers	8	14	10
Clerical	27	22	19
Sales	4	2	7
Blue-collar			
Craft	11	12	12
Operatives	13	1	9
Laborers	1	4	5
Service workers	11	17	17
Farm workers	--	--	--

Note: Data for the 1960 to 1980 periods cover the employed population, 16 years old and over and are derived from population surveys. Data for the 1982-95 period covers jobs and are derived from employer surveys.

Sources: U.S. Bureau of the Census, Statistical Abstract of the United States: 1984, 104th Edition (Washington, D.C.: U.S. Government Printing Office, 1983), Table 693; George T. Silvestri, John M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review, November 1983, Table 1.

Figure 1

The Relationship Between Increasing Levels of Automation and Job Skill Requirements



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SCHOOL OF EDUCATION STANFORD UNIVERSITY

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INTEGRATED CIRCUITS/SEGREGATED LABOR: WOMEN IN THREE COMPUTER-RELATED OCCUPATIONS

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Abstract

This paper examines several aspects of gender segregation within three new computer-related occupations. Using data from the Public Use Samples of the 1970 and 1980 Census, we ask: Are these occupations less segregated by gender than are older occupations? Do these occupations provide an opportunity for women to earn higher salaries than women with equivalent years of educational attainment can earn in other occupations? Do these occupations provide an opportunity for women to earn the same salaries as men with equivalent years of education?

Although it is widely believed that new high technology occupations offer more gender equality than do older, established occupations, especially for those with higher education, we find that there is considerable gender segregation in computer-related occupations as well as considerable male-female salary differentiation. We suggest that one of the major causes of the salary differentiation is that men and women in computer occupations are not employed equally across industries; women tend to be employed more frequently in the lower-paying end-user industries.

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We are just beginning to see the repercussions in all of our lives of the technological feat of fitting the electronic wiring and switches of what was a room-sized computer in 1946 onto a less than fingernail-size piece of silicon and metal by the end of the 1970s. This silicon chip is the core of a technological revolution, the result of many attempts over a century to produce a "computing machine" that is small, fast, and cheap. Now, as the chips, and thus the computers they empower, get smaller, faster, and cheaper, their applications in both old and new products are spawning a new high technology industry. We see changes in a multitude of workplaces and homes, the expansion of opportunities in existing industries and occupations, and the creation of new industries and occupations that were not even imagined just a few years ago.

The occupations most involved in the computer revolution are engineers, computer scientists and systems analysts, programmers, electronic technicians, computer operators and data entry workers; these occupations are expanding both within the computer industry and in other industries as well. In addition, the computer industry provides new opportunities for managers, clerical workers, and production workers.

What do the growth of these occupations imply for women's employment? Traditionally women have been sharply segregated into different occupations from men and have been paid less than men (Gross 1968; Lloyd and Niemi 1979; Blau and Hendricks 1979; O'Neill 1983; Bielby and Baron 1984; Strober 1984; Treiman and Hartmann, 1981). Are there better opportunities for gender integration and earnings equity in new occupations that are growing rapidly and exhibit labor shortages, occupations that are supposedly not driven by past traditions and stereotypes? Are there better opportunities for gender integration and pay equity in high technology (high tech) industries?

The paper is divided into four sections. The first discusses the details of the occupations we analyze. The second section uses published data as well as the 1/1000 Public Use Samples (P.U.S.) from the 1970 and 1980 U.S. Censuses to look at how women are faring in the six major computer-related occupations and in high tech industries. Section three uses the 1980 published data and the 1980 P.U.S. sample to examine the relative earnings of men and women in three computer-related occupations in high tech and non-high tech industries. In section four we discuss our findings and their implications.

In brief, we find that although high tech in general and computer occupations in particular are often seen as the great equalizers, especially for those with higher education, in fact there is considerable gender segregation in both high tech industries and computer-related occupations in all industries; there is also considerable male-female earnings differentiation. We suggest that one possible cause of the earnings differentiation is that men and women in computer occupations are not employed equally across industries; women tend to be employed more frequently in the lower-paying end-user industries.[1]

I. Computer-Related Occupations

A. Descriptions of Occupations

The development of semiconductors, computers, and computer languages spawned several new occupations and expanded several others. There are six major computer-related occupation groups--engineers, computer specialists, engineering and science technicians, production workers, computer operators, and data entry operators. Of the six major groups, three are employed only in the computer industry (engineers, engineering and science technicians and production workers) The other three are employed in virtually all industries. The following descriptions of the occupations in these groups are based on definitions in the Standard Occupational Classification Manual, 1980 (U.S. Department of Commerce, 1980), California Employment Development Department publications (ABAG, 1981), and interviews with workers and employment counselors.

1. Engineers design hardware for computers, including the electronic circuits. The largest group of engineers is electrical engineers, but mechanical and industrial engineers also work in the

computer industry. Sometimes they incorporate software designs into the circuits. Engineering is the highest-status and highest-paid computer-related occupation, with engineers generally having at least a B.S. degree in engineering; many have advanced degrees.

2. As we look beyond designing hardware to designing software, the sets of instructions that tell the computer which operations to perform, we encounter the computer specialist occupations. While computer engineers tend to be employed largely by computer companies, computer specialists are employed in virtually every major industry group.These jobs involve a hierarchy of tasks which used to be done by one person with the title of computer programmer.

When the first computer was unveiled in 1946 (it was room-sized because the circuits were made with glass vacuum tubes), the engineers who designed it thought that the main task of arranging the circuits had been done, and that giving instructions to the computer to perform calculations would be a simple clerical task. So they hired people who usually do clerical tasks--women. In this case the women were recent college graduates with math backgrounds. However, these women found that in order to get the computer to do calculations, they (the programmers) had to know all about the design of the circuits and the way those circuits worked in the computer; they had to tell the computer not only what to do, but how to do it. The simple operation of performing calculations (in this case for Navy shell trajectories), became a high level task which involved a knowledge of logic, mathematics, and electronic circuits. These women programmed the necessary calculations, and went on to do others. However, those who watched the programming process began to realize that programming was a high level, challenging and creative occupation. As the occupation grew, it became largely male (Kraft 1979).

Ironically, some programming today is akin to the type of clerical job which computer designers (mistakenly) thought it would be in the late 1940s. Over time, with the development of higher level languages (closer to human languages)[2] and more routine applications, programming tasks that were previously highly skilled, highly paid, and concentrated among highly educated workers, have been broken down into more routine tasks, distributed among less skilled workers and eventually given over to computers. Kraft (1977) and Greenbaum (1979) have suggested that as this "deskilling" occurs, it is women and racial and ethnic minorities who move into the less skilled jobs.[3]

This history of the developing hierarchy in computer programming is reflected in the designations given by the U.S. Census to the computer specialist occupations. In 1960 and 1970, computer specialists, including programmers, were included in the professional category. By 1980, the Census put the 3-digit occupational category of computer scientists/systems analysts in the professional category and the 3-digit category of computer programmers in the technical category.

The following descriptions attempt to capture the present hierarchy among computer specialists. These job titles and descriptions continue to change and overlap. For that reason it is unclear which job titles were included in the Census categories we used. For instance, it is unclear whether programmers/analysts were grouped with computer programmers or with computer systems analysts.

Computer Scientists and some systems analysts work with engineers to design the overall hardware and software systems, and sometimes know just as much about the hardware, although their training is more concentrated in the logic and mathematical models of computer systems, rather than on electronic principles. They also develop new languages to be used by other programmers. Generally, they have an MS or Ph.D. in computer science (CS) or electrical engineering (EE), or both (CS/EE).

Computer systems analysts conceptualize and plan how a business or industrial task, such as automating a payroll or an assembly line, will be solved by computerization. Systems analysts do not write the programs, but make flow charts to show the subtasks which need to be done by people and computers, and their sequence and timing.

Computer programmers are often promoted into systems analysts positions because these positions represent higher level skills, responsibility, and pay than do programming positions. If systems analysts were not previously programmers, their education is either in business or data processing. There is a debate in this field about whether systems analysts need programming skills or not.

Systems programmers conceptualize and design the operating systems--systems of program which are still principally involved with coordinating all the hardware so that it will run according to certain high level languages. They are responsible for maintaining and modifying the high level software on the system. They generally require a BS, MS, or Ph.D. in CS, EE, or math.

Software programmers or software engineers, as they are increasingly called, design and write programs in high level languages specifically for certain computers. These programs, often called packages, are sold with the computer to make computer use easier for non-programmers. Packages can include such items as games, accounting programs and instructional programs. These can be very creative when they involve conceptualizing and designing new ways to use the computer. Those writing these packages require a good knowledge of the language used to program the package, and good ideas about marketable packages. Consequently, everyone from high school students to Ph.Ds is designing and writing software.

Programmer/analysts maintain individual operating systems and write programs which apply the computer to uses in their own workplace. Although ready-made software is available for many purposes, most firms need programmers to modify or write programs which reflect their own computing needs. These programmers need to know both operating systems and high level languages. Education requirements are a BA in related subjects with some programming experience, a BS in CS or an MBA.

Programmers, sometimes called coders or applications programmers, are mainly translators. They take the instructions for a certain application in one language and translate them into the programming language which their particular computer will use to produce the same results. They do not usually program the operating system. The job category itself encompasses a range of skills and creativeness from routine coding of sections of an application program to a task more like a programmer/analyst, depending upon the industry and firm they are in.

These jobs can be done with less than a BS in CS although in competitive areas, people with higher degrees are hired.

3. A third major group of computer-related workers is engineering and science technicians. This group is found in the computer industry and is mainly made up of engineering technicians trained in electronics, although there are also some science technicians working within the industry. The electronic technicians have enough specialized knowledge of electronics to be able to construct, test and repair the circuitry and components of computers which the engineers design, and to understand engineering specifications and problems. Although they don't do original design work, they operationalize designs, test them, and then advise engineers on possible modifications. They work both in research design and in production to test and troubleshoot both new and existing products. Also included in the engineering technician category are drafters, who, using both manual and computer assisted drafting tools, make drawings of the circuit boards and components which the engineers design. The standard degrees are an AA/AS for engineering or science technician, and an AA in drafting for a drafter.

4. The fourth computer-related occupational group is computer operators. They are employed in all industries. Computer operators run the external operation of the computer, ensure that the computer gets the programs and data, and coordinate disks, tapes and printing connections to the computer, either manually or by supervising automated systems. This occupation ranges from active high-level interactions with the programs to routinized supervision of automated systems. It is sometimes an entry-level job leading to low-level programming. Education needed is simple knowledge of the equipment from a short training course and/or from experience. The occupation is rapidly being deskilled as more of its functions become automated.

5. Data entry operators, the fifth computer-related occupation, put information into a form which can be read by a computer. This information used to be keypunched onto cards, but is now almost always put onto tapes or disks from terminals. The operators, who basically type numbers and

letters into a terminal, require training in typing. They are also employed in all industries.

6. The sixth major computer-related occupation is production worker. While many of the production jobs are similar to those in other industries, the following jobs are unique to semiconductor and computer production. There are generally no specific educational requirements for these jobs, although in competitive labor markets people with some knowledge of electronics are preferred. Often hazardous chemicals are used in the production process.

Semiconductor processors put materials through chemical and mechanical processes to create semiconductor integrated circuits on chips. They work either manually or, as these tasks become mechanized, with processing machines.

Semiconductor assemblers assemble chips into wired devices which become the complete integrated circuit. This includes bonding wires to circuits, a task which is done under a microscope, and cleaning the circuits with chemicals.

Electronic assemblers assemble the integrated circuits and other electronic components into a frame which becomes the finished product (eg. a computer). Electronic assemblers can be promoted to electronic testers, who test chips, boards and components as they go through assembly, or electronic inspectors, who examine the components for errors and specification requirements.

A skilled occupation which is sometimes part of production and sometimes in customer service is data processing repairing, installing and repairing data processing machinery in offices and on production lines. This job category includes a range of workers from electronic mechanics to assembly and wiring technicians.

There are also, of course, sales, managerial, and professional occupations within the computer industry. These jobs tend to be similar to such jobs in other industries.

II. Gender Segregation

A. Computer-Related Occupations

Table I gives the total number employed and the percentage of women employed in the total labor force and in computer-related occupations in 1970 and 1980.[4] Between 1970 and 1980, employment in computer-related occupations grew about 80 percent--from about 1.5 million to 2.4 million. However, although the growth of these occupations is widely heralded, it is important to note that they represented only 2.0 percent of all employment in 1970, and 2.5 percent in 1980.

In 1970, women were 38 percent of the U.S. labor force; in 1980, they were 43 percent. In both those years, women's representation in computer-related occupations was either considerably below or considerably above their representation in the labor force as a whole. Despite the fact that the computer-related occupations are of relatively recent origin, they are already remarkably segregated by gender.

In 1970, women were 2 percent of all engineers in the computer industry; in 1980, that figure had risen to only 5 percent. Thus, in the highest paid, highest prestige computer-related occupation, women are virtually absent.

Among computer specialists in all industries, the situation is somewhat better, although women are still below their proportion in the overall workforce. In 1970, women were 15 percent of all computer scientists/systems analysts. This occupation more than doubled from 1970-1980 (from 93,000 to 200,700), but by 1980, women were only 22 percent. Among programmers, the proportion of women also increased, but they were also still underrepresented. The number of programmers almost doubled (from 161,000 to 313,000), and the proportion of women grew from 23 percent in 1970 to 31 percent in 1980.

Women were better represented among engineering and science technicians in the computer industry than among engineers, but were less well represented than among computer specialists. In 1970 in the computer industry, women were 11 percent of engineering and science technicians; in 1980 they represented 17 percent. They were similarly represented among electronic/electrical technicians--11 percent in 1970 and 15 percent in

1980. As drafters, women did less well in 1970 than other technicians--only 7 percent were women-- but did better in 1980, when 16 percent were women.

Initially, there was no clear indication as to which gender would be assigned to the occupation of computer operator. In 1960, when there were only 2,000 computer operators, women held 65 percent of the jobs (Dicesare, 1975). Between 1960 and 1970, the jobs in this occupation increased more than 50 fold, to 117,000. More of these new jobs were filled by men than by women so that in 1970, women were only 29 percent of all computer operators. In the period from 1970 to 1980, however, while the occupation increased four-fold, to 408,000, more of the new additions to the occupation were women, so that in 1980, women were 59 percent of all computer operators.

Like most clerical occupations, data entry is preponderantly female. In 1970 women were 90 percent of data entry operators. Between 1970 and 1980 the occupation became even more segregated so that by 1980 women represented 92 percent of such operators.

Of all production workers in the computer industry, women were only slightly over their representation in the labor force as a whole: 46 percent in 1970 and 49 percent in 1980. However, when we look more closely at the less skilled production occupations, women's representation is much higher. Of all the operatives, fabricators, laborers, and transportation workers, a group which includes the semiconductor processors and assemblers and all other lower level production workers in the computer industry, women represented 58 percent in both 1970 and 1980. Among assemblers, a sub-set of operatives, women were about 73 percent in 1970 and 1980. Of electronic assemblers, a group identified only in 1980, women were an even higher proportion: 77 percent.[5] However, in the occupation "data processing machine repairers," we find again the extraordinary gender segregation we often see in technical occupations: women held 3 percent of these jobs in 1970, 8 percent in 1980.

B. Gender, Race, and Ethnic Distribution in Four Computer-Related Occupations

If we look more closely at the four computer-related occupations which are present in all industries--computer scientists/systems analysts, computer programmers, and data entry operators--we can see how women and men in the three largest racial and ethnic groups are represented. Table II shows that in the employed labor force as a whole, white men are 50 percent of the workers, white women are 36 percent, black men are 4.8 percent, black women are 4.8 percent, and other racial groups make up 8.4 percent of the workers. Men and women of Spanish origin, who can be of any race, represent 3 and 2 percent of the workers respectively.

In the occupations of computer scientists/systems analysts and computer programmers, women of all groups and minority men are underrepresented compared to their representation in the labor force as a whole, while white men are overrepresented. Within each racial and ethnic group, men are better represented than women.

In the highest paid category, computer scientists/systems analysts, white men hold 71.3 percent of the jobs, much higher than their representation of 50 percent in the labor force. White women occupy 19.5 percent of the jobs, only half as high as their representation in the labor force. Black men are less represented in this occupation than in the labor force (3 percent versus 4.8 percent). Black women's representation is even poorer, with 1.7 percent in computer scientists/systems analysts versus 4.8 percent in the labor force. People of other races are only about half as well represented in this occupation as in the labor force. Like black men, the representation of men of Spanish origin is just over half that of their presence in the labor force (1.8 versus 3 percent). Women of Spanish origin are virtually unrepresented; they are only .1 percent of computer scientists/systems analysts, though they are 2 percent of the labor force.

Among computer programmers, the next lower paying occupation, white men are still overrepresented, and the other groups are still underrepresented, but somewhat less so. White men are overrepresented by 10 percentage points (62.2 percent versus 50 percent) and white women are underrepresented by 10 percentage points (26.5 percent versus 36 percent). Black men's representation is still 3.1 percent, but black women's representation has increased to 2.5 percent. However, both percentages are below their share of the labor force. Other racial groups have also increased their representation, but it is still below their labor force representation. Men and women of Spanish origin have virtually the same representation among computer programmers as among computer scientists/systems analysts--1.8 and .1 percent respectively.

This situation changes and in some cases reverses itself in the lower paying occupation of computer operators. White men are now only one third of the workers, 10 percentage points less than in the labor force, and white women are now half of the workers, 15 percentage points above their representation. Black men's representation is about the same as in the labor force, and black women's representation is higher among computer operators (6.9 percent) than in the labor force (4.8 percent). People of other racial groups are still underrepresented, however. Men of Spanish origin have a representation among computer operators just below their labor force percentage, while the percentage of women of Spanish origin is slightly above their percentage in the labor force. Thus in this lower paid computer occupation, white and black women and women of Spanish origin are slightly overrepresented, and white men are underrepresented, while the percentage of black men and men of Spanish origin reflects their percentage in the labor force as a whole.

When we look at the lowest paid computer occupation of data entry operator, a clerical occupation, we see that all women's representation is dramatically higher and all men's representation dramatically lower than for the other occupations listed in Table II. White women are 71 percent of data entry operators, twice their labor force representation. Black women and women of Spanish origin are represented in this occupation with a frequency three times greater than their representation in the labor force, 16 and 6 percent respectively.

Like gender, race and ethnicity of workers in computer occupations is associated with pay and status of the occupation. The higher status and pay of an occupation, the more white men are overrepresented, and the more minority men and all women are underrepresented. In occupations with lower pay and status, the presence of white men drops to much below their percentage of the labor force, the percentage of women of all races becomes higher than their labor force percentage, and the percentage of minority men approaches their labor force representation. In an occupation which is clerical, women's representation doubles and triples above their labor force percentage, and men virtually disappear.

C. High Tech Industries

This section looks at how women are faring not just in computer-related occupations but in the group of industries known as high tech, of which the computer industry is one part. We are interested in whether or not the computer industry and other high tech industries, because they are growing rapidly and are relatively new, are therefore perhaps less gender stereotyped and more hospitable to women than are non-high tech industries.

The Bureau of Labor Statistics recently reviewed all current definitions of high tech industries, and developed a range of definitions based on three factors: "(1) the utilization of scientific and technical workers, (2) expenditures for research and development, and (3) the nature of the product of the industry." (Riche, et al., 1983).

Different combinations of these factors produced three groups of high tech industries, from the least inclusive definition with 6 three-digit industries, to the most inclusive definition with 48 three-digit industries. We use as our definition of high tech industries the middle group of 28 three-digit industries: 26 manufacturing industries (including computers and semiconductors) with a proportion of technologically-oriented workers equal to or greater than the average for all manufacturing industries and a ratio of R & D expenditure to sales close to or above the average for all industries, and two non-manufacturing industries that provide technical support to high tech manufacturing industries (computer and data processing services, and research and development laboratories). (Riche et al. 1983). A list of the industries designated as high tech may be found in Appendix I.

We find, however, that these industries are no less segregated by gender than are other industries, and in fact may be even more so. Table III demonstrates that employment in high tech industries has grown over the 1970-80 decade from 4.6 million to 6.1 million. In both 1970 and 1980, high tech industry employed only about 6.5 percent of all employed workers, about 5 percent of all women workers and about 7.4 percent of men workers.

Table IV shows that in both 1970 and 1980, most men in high tech industries were in management, professional/technical work, or in production, while most women were in clerical work or production. Compared to women in non-high tech industries, women in high tech industries are less likely to be in managerial and professional/technical jobs, and much more likely to be in production work. High tech industries provide lower status occupations to women, as a group, then do non-high tech industries. By contrast, men in high tech industries are more likely to be in managerial or professional/technical positions than are men in non-high tech industries.

III. Analysis of Relative Earnings of Women and Men in Three Computer-Related Occupations

A. Uncorrected Earnings Differentials

To examine salary differences between women and men we analyze three computer-related occupations where at least 20 percent of the jobs are held by the "minority gender"--computer scientists/systems analysts, computer programmers, and computer operators.[6] We find that even when women are employed in the same occupations as men, they do not receive the same pay.

We used two sources to calculate the gender differential in pay--the published Census reports, where the only available measure was the mean annual earnings, and the Census P.U.S. samples, where we could calculate the median hourly earnings. With each source, for the years available, we calculated the ratio of the women's earnings to men's earnings for each of these three occupations in all industries combined. As each source has both advantages and disadvantages, we present data from both.

The advantage of using the published Census reports is that they are more accurate than the samples. The disadvantages are that only the mean annual earnings are available for 1980, and the mean is a poor estimate of average earnings since it is so influenced by a few high values. In addition, since the median was used as an estimate for most of the comparable occupations in 1970, the two years could not be compared, except in the combined category of computer specialist. Another disadvantage is that the use of annual earnings precludes controlling for part-time or part year workers.

The advantages of using the Census samples are that we could calculate the median, the most accurate estimate for average earnings, for each occupation and year; and could control for part-time and part year workers by calculating the hourly earnings.[7] The disadvantage is that the estimates were subject to large standard errors.

Interestingly, the two sources of income data produced simlar and consistent results. Table V contains the uncorrected gender differentials in pay based on the published Census data. In the first two columns are the numbers (in thousands) of total employees (men and women) in each occupation in 1970 and 1980. The second two columns show percentage of all employees who were women in each year. The next four columns show, for the years it was available, the mean annual earnings of men in that occupation, and the ratio of women's mean hourly earnings to men's earnings. This ratio is the gender differential in pay for each occupation, with no controls for education or experience.

For the combined computer specialist occupations, the uncorrected ratio of women's to men's mean annual earnings was .72 both in 1970 and in 1980. This constancy of the ratio is noteworthy as employment more than doubled over the ten year period and the proportion of women in these occupations increased by 50 percent.

In 1980, the uncorrected ratio of women's to men's mean annual earnings was available for the three occupations. For both computer scientists/systems analysts and computer programmers, the ratios were .73. For computer operators the ratio was .65. Since these were not corrected for part-time or part year workers, we would expect the ratio estimates which did have these corrections to be somewhat higher, and they were.

Table VI contains the gender differentials in pay based on the P.U.S. samples, corrected for part-time and part year workers but not for education or experience. In the first two columns are the sample numbers of men and women employed in each occupation in 1970 and 1980. These numbers are the samples upon which the earnings estimates are based. The second four columns show, for each year, the median hourly earnings of men in the occupation, and the ratio of women's median hourly earnings to men's earnings.

For the occupation computer scientist/systems analyst, the ratio of women's to men's median hourly earnings was .75 in 1970, and .74 in 1980. Again, such constancy is noteworthy since employment more than doubled over the decade. It is also interesting that correcting for part-time and part year workers does not increase this differential to much above the estimate from the published data for computer specialists.

Among programmers, there was still a gender differential after correcting for part-time and part year workers, earnings, although smaller than that for computer scientists and systems analysts. The ratio of women's to men's median hourly earnings was .85 in 1970, .83 in 1980—again, remarkably constant given the more than doubling of employment in the occupation.

For computer operators there was a rise in the differential with the correction for part-time and part year workers. In 1970, when women had only 29 percent of the jobs, the female/male ratio of median hourly earnings was .73. By 1980, the gender division of labor had reversed and women dominated the occupation, with 59 percent of all the jobs. Still, the earnings ratio was .69, quite close to what it had been ten years earlier.

Although the sources are based on different measures and samples, they both show that women earn substantially less than men in these three occupations and that these ratios do not change much over time. Clearly, earnings equity is not an automatic result of the existence or the growth of these occupations.

Despite the fact that women earn less than men in computer programming and computer science/systems analysis, professional computer-related occupations are financially attractive for women. Relative to what professional women earn in other occupations requiring similar years of educational attainment, computer programming and systems analysts positions enable women to earn at the top of the female earnings hierarchy. Table VII shows that for women in 1981, computer systems analysts was the second-highest paying occupation, computer programming the seventeenth highest. In both of these occupations, women earned more on average than they did in secondary school teaching (Rytina, April 1982), despite the fact that in 1980 the mean educational attainment was only 15.75 years for women systems analysts and only 14.88 years for women computer programmers. For women secondary school teachers, the mean educational attainment was 16.43 years (P.U.S., 1980).

B. Earnings Regressions

Earnings differentials between women and men in the same occupations are in part a result of differences between women's and men's human capital and productivity and in part a result of wage discrimination (lower payment to women even after human capital and productivity have been held constant). To what extent is wage discrimination against women present in the relatively new computer occupations? Does employment in a high-tech industry lessen wage discrimination within the computer occupations?

In order to answer these questions, we ran OLS regressions for the three computer-related occupations in 1970 and 1980, on the natural log of hourly earnings using the P.U.S. samples. The independent variables we used to proxy human capital and productivity were determined by the availability of data. The Census 1/1000 P.U.S. reports age, years of education, and gender, but not years of work experience, type of degree or field of college major. We used AGE and AGE^2 as continuous variables. We divided years of education into six categories, reflecting the fact that number of years of education affects one's position in the labor market in a discontinuous fashion. The categories are: eight years or less; some high school; high school graduate; some college; college graduate; and more than a college degree. The category "some college" was the reference group and was omitted from the regression.

These variables have some serious deficiencies as indicators of education and productivity. Although age is often used as a proxy for work experience, a component of human capital, age is less likely correlated with years in the labor force for women than it is for men, and is therefore a less than satisfactory proxy for experience. Level of education, although frequently used as a measure of human capital and productivity, says nothing about the quality or type of education. Because our controls for human capital and productivity are problematic, the gender variable is a poor measure of discrimination.[8] We use age and level of education as control variables only because we have no others; we have traded-off poor human capital proxies for the relatively large samples of these three occupations which the Census provides.

In addition to human capital variables the regressions have two dummy variables: GENDER (equal to one for women) and HTECHIND (equal to one for those employed in a high tech industry). The combined effects of the human capital variables and the two dummy variables on salary were tested in an additive model.[9]

For computer scientists/systems analysts in 1970, age, education, gender, and industry type explained 20 percent of the variance in the log of hourly earnings (see Table VIII); however, only having a college degree and older age were significantly related to earnings. By 1980, only 10 percent of the variance was explained by these four factors. Age and a college degree still significantly increased earnings, but gender less significantly decreased earnings. Holding the other variables constant, having a BA or BS increased one's salary by 27 percent while being a woman decreased it by 20 percent. The drop in explained variance suggests that by 1980 other unmeasured factors were beginning to affect salaries for this occupation. Being in a high tech industry was not significantly related to earnings for computer scientists/systems analysts.

For computer programmers, we saw a more dramatic trend. In 1970, education, age, industry and gender explained almost none of the variance. However, by 1980, 20 percent of the variance was explained by these factors and all but industry type were significantly related to earnings. Age, and having a BA/BS, and more than a BA/BS significantly increased earnings, while gender, somewhat less significantly, decreased earnings. The changes in the effects of age and education may reflect the formalization of qualifications for this occupation; whereas earlier, people with diverse education and experience were recruited and trained into it, by 1980 there were more formalized career ladders and more institutional training in the field. The beginning of an effect based on gender suggests that some differences based on gender may also have been in the process of becoming institutionalized. For programmers, being in a high tech industry did not appear to affect salaries when other variables were held constant.

Computer operators show a different pattern. For both 1970 and 1980, 16-20 percent of the variance was explained by age, industry, education and gender. Being a woman decreased one's salary significantly in both years. In 1970, gender was the only significant variable in the regression; being female, all other variables held constant resulted in a 70 percent decrease in salary. By 1980 higher age and working in a high-tech industry also contributed significantly to higher earnings, but education was still not significant. In 1980, the effect of gender on salary, while still highly significant, was much smaller (27 percent) than it had been in 1970. These results reflect the fact that this occupation has few educational requirements, that training is largely on the job, and that jobs in high tech industries pay more. However, it also points out that women with the same education and age are still paid less than men, and that this was true both when the occupation was predominantly male (in 1970) and when it was predominantly female (in 1980).

C. A Closer Look at Earnings and Employment Differences by Industry

How does the labor market operate to pay men and women differentially even when they are in the same occupation, and are similar with respect to age and level of education? In her book on clerical employment, Francine Blau (1977) reports that often women and men in the same occupation in the same city earn different salaries because they work for different firms--women for low wage firms and men for high-wage firms. It may be that, analogously, women and men in computer occupations earn different salaries in part because they work in different industries--men in high paying industries and women in lower paying "end-user" industries.

These differences may not have shown up in the reported regressions because the industry dummy variable divided industries into only two groups, high tech and non-high tech. Unfortunately, the P.U.S. sample sizes in each industry are too small to include major industry groups as variables in the reported regressions. However, Table IX, based on the Census publication, Occupation by Industry shows that within these three computer-related occupations in 1980, women and men are not employed in equal proportions across major industry groups.

In the first column of Table IX we find the estimated number of total employees (men and women) in each occupation by industry. The second column contains the percentage of women in the occupation for each industry. The third column shows the men's mean annual earnings in the occupation by industry. In the fourth column we have calculated the ratio of the women's mean annual earnings to men's mean annual earnings for each industry. The first row of each occupation contains these data for all industries combined. The second row isolates these data for part of the computer industry, based on the Census 3-digit industry category, "Electronic Computing Equipment Manufacturing." The remaining rows show the data in the major 2-digit industry groups. Several industry groups (agriculture, forestry and fishing; mining; construction; personal services; and entertainment and recreation) have been removed from the analysis altogether because they employ so few persons in computer-related occupations.

As shown in Table IX, women are 22.3 percent of computer scientists/systems analysts, in all industries, but only 14.9 percent of computer scientists in electronic computing equipment manufacturing. Among the major industry groups listed in Table IX, the percentage of women employed ranges from 16.9 percent in mining to 35.6 percent in finance, insurance and real estate. For all industries, the men's mean annual earnings for computer scientists/systems analysts is $23,405; earnings figures are not available for electronic computing equipment manufacturing. Among major industry groups, men's mean annual earnings range from a low of $20,296 in professional and related sciences to a high of $26,031 in mining. Note that in mining, where the percent women employed is lowest, men's earnings are highest; conversely, where the percent women employed is highest (in finance, insurance and real estate) men's earnings are the second lowest.

To examine the relationship between the percent women and men's mean annual earnings across major industry groups we computed a rank correlation coefficient. For computer scientists/systems analysts the rank correlation coefficient is -.95, significant at the 99 percent confidence level. However, because the sample sizes are relatively small, we also computed the rank correlation coefficient taking into account the standard errors of the percentages and means.[10] The corrected rank correlation coefficient is -.68, not significant at the 95 percent confidence level.

The ratio of female/male earnings (F/M) for computer scientist/systems analyst is .73 for all industries and ranges from .69 in manufacturing to .82 in transportation, communications and public utilities. The data do not suggest a relationship across industries between F/M and percent women or between F/M and men's mean annual earnings, mainly because of the lack of wide variation in the F/M ratio.

Among computer programmers, women are 31.1 percent of employees in all industries but only 22.0 percent in electronic computing equipment manufacturing. As in the case of computer scientists/systems analysts, women are more likely to be employed in end-user industries. Across major industry groups, the percent women employed ranges from 26.5 in manufacturing (which includes the manufacturing of electronic computing equipment) to 36.6 percent in finance, insurance and real estate. Men's mean annual earnings are $17,967 for all industries; among major industry groups, they range from a low of $12,353 in professional and related services to a high of $19,704 in transportation, communications and public utilities. However, unlike the situation for computer scientists/ systems analysts, neither the uncorrected nor the corrected (for standard error) rank correlation coefficient show a significant relationship between percent women and men's mean annual earnings.

The ratio of F/M earnings for programmers does not vary very much across major industry groups. The ratio for all industries is .73; for all but one major industry group, the F/M earnings ratio is within a few percentage points of the mean. However, in professional and related services the ratio is .83. It is interesting that in this industry men's earnings are the lowest for all of the industries listed.

Among computer operators, women are 59.0 percent of those employed in all industries, but only 46.6 percent of those employed in the manufacture of electronic computing equipment. As in the case of computer scientists/systems analysts and computer programmers, women computer operators are more likely to be employed in end-user industries than in the computer manufacturing industry. Among major industry groups, the percent of women employed ranged from a low of 42.9 percent in mining to a high of 68.8 percent in construction.

Men's mean annual earnings were $14,203 for all industries and ranged from a low of $10,024 in professional and related services to a high of $17,067 in transportation, communications and public utilities. There is no systematic relationship between men's mean annual earnings and percent women.

The ratio of F/M earnings for computer operators was .65 for all industries. As in the case of the other two occupations discussed, the F/M earnings ratio did not vary much across industries. The only "outlier" was in the professional and related services industry where the ratio was .80. And, as in the case of computer programmers, this industry had both the highest F/M earnings ratio and the lowest men's mean annual earnings.

Our data suggest that in computer occupations, women are more likely to be found in end-user industries than the computer manufacturing industry itself. In some occupations, particularly computer scientists/systems analysts, women also may be more likely to be found in industries where men are lower-paid.[11] However, it is not possible at this point to test this hypothesis definitively. If we were to disaggregate industry groups further, the sample sizes would become even smaller and the standard errors would rise accordingly.

IV. Conclusions

A. Findings

1. Despite the fact that computer-related occupations are of recent origin, they are not gender-neutral. The computer field was sired by the fields of mathematics and engineering and the newly born prestigious and technical jobs quickly took on the gender designation of the parent fields. Computer engineering and electronic technical work have very few women. On the other hand, data entry, which quickly took on the characteristics of clerical work, became a virtually exclusive female preserve. Production work, too, is preponderantly female (see Table I).

Computer programmers were female when the occupation first emerged, but very shortly after the computer was introduced, men began to fill the emerging jobs. Although women have increased their representation in the jobs of both programmer and analyst, women remain less than a third of the incumbents of these occupations. While the occupation of computer operator did not seem to be immediately gender typed, in that it was preponderantly female in 1960 and male in 1970, it was becoming preponderantly female again by 1980.

2. Among four computer related occupations found in all industries--computer scientists/systems analysts, computer programmers, computer operators, and data entry operators--the higher the status and pay of the occupation, the more white men were overrepresented compared to their representation in the labor force as a whole and the more minority men and women of all racial and ethnic groups were underrepresented. In occupations with much lower pay and status, the presence of white men dropped to much below their percentage in the labor force, the percentage of women of all racial and ethnic groups became much higher than their percentage of the labor force, and the percentage of minority men approached their labor force representation (see Table II).

3. Within high tech industries, most men were in production, professional/technical, or managerial occupations, while most women were in production or clerical occupations. Women and men were equally likely to be in production occupations. However, men were more likely to be in managerial and professional/technical occupations in high tech industries than in non-high tech industries; women fared worse in these occupations in high tech industries than in other industries (see Table IV).

4. Within the occupations of computer scientists/systems analysts, computer programmers, and computer operators, women's mean annual earnings and women's median hourly earnings were less than those of men. In addition, the ratios of women's to men's earnings generally remained constant between 1970 and 1980 (see Tables V and VI).

5. Within the three occupations analyzed, women's hourly earnings were generally less than those of men even after age, level of education, and high tech versus non-high tech industry were held constant (see Table VIII).

6. Women employed as systems analysts, programmers and computer operators were more likely to be found in end-user industries than in the computer manufacturing industry itself. Within the three computer-related occupations, women were paid less than men no matter in what industry they were employed (see Table IX). In some occupations, particularly computer scientists/systems analysts, women may be more likely to be found in industries where men are lower-paid. However, this hypothesis has not been tested definitively here.

These findings dispel the myth that high tech is automatically a great equalizer. High tech may produce integrated circuits, but it does not necessarily produce an integrated work force or eliminate the female/male earnings differential.

B. Discussion

A detailed explanation of these findings is beyond the scope of this paper. Several theories have been proposed to explain occupational segregation and earnings differentials by gender (see Blau and Jusenius 1976; Cain 1976; Amsden 1980; Sokoloff 1980; and Strober 1984). These theories focus on women's own behavior, on employer discrimination, and on the interactions of labor markets and gender relations in society. It is likely that all of these theories explain aspects of the pattern of gender segregation and earnings differentials reported here and that several different types of policies will be required if we wish to change these patterns.

More research on the dynamics of each aspect of gender segregation would allow us to design more effective policies. More detailed research on the differences in women's employment between and within industries and between and within firms would identify the bottlenecks toward the gender integration of occupations. Attention needs to be given to the processes by which women are allocated, and/or allocate themselves into the lower paid occupations and industries. This involves investigating how employers structure and define occupations and career ladders and distribute skilled job applicants and workers in ways that result in gender segregated occupations and industries. Research also needs to be done on the degree to which technologically-trained women (and some men) self-select out of certain occupations or industries because a certain definition or culture for the occupation or industry precludes respect for the participation of people with different work styles or cultures.

As compared to men, women still are more likely to exclude themselves from advanced science and math training; DeBoer (1984) argues that even when women in high school and college science perform at a higher level than their male classmates they have a higher drop out rate from science than do men. He proposes that teachers in secondary and post-secondary education make special efforts to let talented women know how skilled they are.

However, Sally Hacker's work (1981) suggests that merely encouraging women may not be sufficient to change their educational decisions, that women's decisions to exclude themselves from technical fields may be related in part to a dislike of the fields' "culture". Hacker, based on research at a technical institute, argues that there is a "culture of engineering" which includes an extension of the profession's formal objectification and control of the natural world to an informal objectification of women.

It may be that a distaste for being part of the "engineering culture" also leads technically trained women to exclude themselves from certain sectors of the computer industry. If an engineering culture appears most strongly in those sectors and industries of the computer field that are at the technological forefront and most competitive technologically, then it may be that those sectors and industries are the least appealing to women. However, it may not be accidental that these sectors have the strongest engineering culture. In terms of Strober's theory (1984), men who work in these intellectually challenging and highly lucrative sectors may develop the "engineering culture" in part precisely to keep women out.

The work style and work pressures in the most technologically competitive sectors of the computer industry may also keep many women out. While firms in all industries must remain competitive with similar firms, the computer industry, a new industry with constant technological breakthroughs, has some unique pressures: to make and increase profits in a competitive non-oligopolistic environment, stay on the technological forefront, and stay ahead of not only young and old domestic companies, but their Japanese counterparts as well. These financial and technological pressures are intensified as each firm tries to survive and succeed before the industry "shakes down". There is much pressure on workers in the computer industry to maintain high levels of productivity, including overtime work and other forms of commitment to the success of the firm. Women who want to succeed have to put in long, hard hours of work, and this may be a barrier for women (and men) who are trying to balance their home and work lives.

Even as we encourage more women to train for the highly technical computer occupations, we need to disseminate the findings of studies such as this. Women need to be made aware of the chanelling that leads them into less prestigious, lower paying occupations or industries and be helped to develop strategies to counteract this chanelling. At the same time, if we are interested in ending gender segregation and attendant gender pay differentials, we need to find ways of making occupations and workplaces more welcoming to both genders and more compatible with satisfying personal and family lives.

NOTES

[1] We define "end-user" industries as those which use the products of the computer industry and make only minor changes to accommodate the products to their needs, rather than making basic new developments in these products. The companies developing computers and/or their software are part of the computer industry. The companies in all other industries, which will use these computers and/or software, are part of end-user industries.

It is true that even within the computer industry the administrative divisions of the companies are end-users of computers. However, Census data does not permit us to make such fine distinctions within industries, and we are interested here in any broad differences between industries.

[2] Note that higher level languages are closer to human languages and hence easier to use in programming. Thus, paradoxically, "higher" level languages require lower skill and have lower prestige associated with their use.

[3] Braverman (1974) originally identified and labeled this process as the "degradation of work". It soon became known as "deskilling".

[4] This table contains two levels of aggregation--computer-related occupations found mainly within the computer industry, and those found in all industries. For the three occupational groups within the computer industry (engineers, engineering and science technicians, and production workers), we used the published U.S. Census Population Characteristics Special Report, Occupation by Industry for 1970 (Table 8) and 1980 (Table 4). The computer industry was defined as two 3-digit industry categories: Electronic Computing Equipment and Electrical Machinery, Equipment, and Supplies, n.e.c. (which includes semiconductors). For the computer-related occupations which were represented in all industries, we used the same reports, Table 8 (1970) and Table 1 (1980). The notes for Table I indicate the detailed occupational categories used for each occupational group.

[5] In Silicon Valley in 1981, 40 percent of women assemblers were ethnic minorities (Rogers and Larsen, 1984). This production occupation is even more segregated if we consider the thousands of women, but absence of men, employed as assemblers in American electronics factories abroad (Grossman, 1980).

[6] Although production workers also qualified under the criterion, we did not study them, because they are only "computer-related" if they are in the computer industry, and isolating that industry would have created too small a sample. In addition, we wanted to compare computer-related occupations

across industries, and computer-related production workers by definition cannot be in other industries.

[7] Hourly earnings were calculated by dividing each person's yearly salary (from the year prior to the Census year) by the number of weeks worked (in the year prior to the Census) and dividing that by the hours they worked in an average week. Because the data are based on the respondents' estimate of the average hours worked, the data are subject to possible errors.

[8] See Strober and Reagan (1982) for a discussion of the problems of using regression techniques to measure discrimination.

[9] We also ran regressions with the education and high tech variables interacted with gender, testing a multiplicative model. However, since no interactions were significant in 1980, since the few interaction terms that were significant in 1970 could have been so by chance, and since most residuals in the additive model were acceptable, we followed the usual statistical practice of reporting the more parsimonious model. (See Chatterjee and Price, pp. 78-85). While the residuals for computer operators in 1970 were improved by adding interaction terms to the equation, we used the additive model for this occupation and year for consistency, and because these interaction terms could have been significant by chance.

When variables are added to an equation not from an a priori expectation of their effect but rather merely to test for their effect, as in the case here, there is a 5 percent chance that a significant effect may occur only by chance. The more variables, the more chance that one or more will be falsely significant. Likewise, the more regression equations, the more chance that one will contain falsely significant variables. (See Wonnacott and Wonnacott, pp. 88-94.) Since the equation with the interaction terms had 15 variables in it, and was run six times (for three occupations in two years), it seemed likely that the few interaction terms that were significant might well have been so only by chance.

[10] The standard errors for the percentages were calculated from Table B or the formula below the table in Appendix C in Occupation by Industry. This was multiplied by 1.2, the appropriate design effect factor for a crosstabulation of industries and occupations, as shown in Table C of Appendix C. A 95 percent confidence interval was created by calculating two standard errors on either side of the estimate.

The standard errors for means were calculated using the formula in Appendix C, page C-2, for standard errors of means. The variances needed in that formula were not provided by the Census, so a conservative guess was used of a standard deviation equal to 5,000 for all salary distributions. This was squared to produce the estimated variance. A 95% confidence interval was created by calculating two standard errors on either side of the estimate.

[11] Kraft and Dubnoff found similar results in a 1982 survey of "software specialists" in Boston. They found women concentrated in the "worst paying industries" (Kraft & Dubnoff 1983).

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APPENDIX I.

Industries Within Major Industry Groups, by High Tech and Non-High Tech Categories

(High tech/non-high categories from Monthly Labor Review [Riche, *et al.*, 1983]. Industry groups and titles from 1980 Census Industry Codes.)

HIGH TECHNOLOGY INDUSTRY GROUPS (HIGH TECH):

Durable Manufacturing

Ordnance, engines, turbines, industrial machines, office and accounting machines, computers, electrical equipment and industrial apparatus, radio, TV, communications equipment, electronic components, accessories, and machinery, aircrafts and parts, guided missiles and space vehicles, engineering, laboratory, scientific, and research instruments, measuring and controlling instruments, optical, surgical, medical, and dental instruments, photographic equipment.

Non-durable Manufacturing

Chemicals, plastics, synthetics, drugs, soaps, cleaners, paints, petroleum refining.

Business and Repair Services

Computer and data processing services, commercial research and development laboratories.

NON-HIGH TECHNOLOGY INDUSTRY GROUPS (NON-HIGH TECH)

Durable Manufacturing

Lumber, furniture, stone, clay, and glass products, other metal industries, cut~~lery,~~ handtools, hardware, other machinery, household appliances, transportation equipment, clocks, toys, sporting goods.

Non-durable Manufacturing

Food, tobacco, textile, apparel, paper, printing, rubber, leather products.

Business and Repair Services

Advertising, buildings services, personnel supply, business management and consulting, detective and protective services, business services, automotive services and repair, electrical repair, misc. repair.

Transportation, Communication, and Public Utilities

Rail, bus, taxi, truck services, warehouses, U.S. Postal Service, water and air transportation, pipelines, misc. transportation services, radio, TV, telephone, telegraph, electricity, gas, steam, and water supplies, sanitary services.

Wholesale Trade

All wholesale trade of durable and nondurable goods, including sale of high tech products.

Retail Trade

All retail outlets for durable and nondurable goods, including sale of high tech products.

Finance, Insurance, and Real Estate

Banking, savings, and loans, credit agencies, securities and investment, insurance, real estate and real estate insurance and law offices.

Professional and Other Services

Offices of doctors, dentists, chiropractors, optomitrists, and other health practitioners and services, hospitals, nursing, and personal care services, legal services, elementary and secondary schools, colleges and universities, business, trade, and vocational schools, libraries, educational services, job training and vocational rehabilitation, childcare services, residential care, social services, museums, art galleries, zoos, religious and membership organizations, engineering, architectural, and surveying services, accounting, auditing, and bookkeeping services, noncommercial educational and scientific research.

Public Administration

Offices of chief executive and legislative bodies and their advisory and interdepartmental committees and commissions, government civil rights and civil service commissions, offices providing support services for government such as accounting, personnel, purchasing and supply, courts, police protection, correctional institutions, fire protection, government legal counsel, public finance, tax, and monetary policy, administration of educational programs, public health programs, social, manpower, and income maintenance programs, veterans' affairs, environmental protection, and housing and urban development programs, regulatory agencies, national security and international agencies.

NOTES:

Detailed occupational categories represented by the occupational titles in Table I, based on the occupatonal 2-digit and 3-digit codes from the 1970 and 1980 U.S. Census:

*Engineers: The 2-digit category of engineer.
The 3-digit category of electrical/electronic engineer.
Computer Specialists: The 3-digit category of computer scientists/systems analyst.
The 3-digit category of computer programmers.
*Engineering and Science Technicians: The 2-digit categories of engineering and science technicians.
The 3-digit category of electrical/electronic engineering technicians.
The 3-digit category of drafters.
Computer Operator: The three 3-digit categories of computer equipment operators and supervisors.
Data Entry Operators: The 3-digit category of data entry operator.
*Production Workers: Over 200 3-digit production occupations, including crafts, precision production, operatives, transportation and laborers. Does not include farm occupations.
*Operatives, Fabricators, Transportation, and Laborers: A subset of production workers. Excludes craft workers and precision production. Not precisely the same occupations in each year.
*Assemblers: The 3-digit category within the operatives group.
*Electronic Assemblers: A 3-digit category in 1980 only, within precision production.
Data Processing Repairers: Within precision production, the 3-digit category of data processing repairer.

*Only reported within the detailed industry groups: Electronic Computing Equipment and Electrical Machinery, Equipment, and Supplies, n.e.c. (includes semiconductors).

TABLE I

Total Employed in the Labor Force and in Computer-Related Occupations, 1970 and 1980

	1970		1980	
	Number Employed	Percent Women	Number Employed	Percent Women
Total Labor Force	76,553,599	38	97,639,355	43
Total in Computer-Related Occupations	1,497,461	--	2,424,240	--
*1. Engineers	90,626	2	125,055	5
*Electrical/Electronic Engineers	47,004	2	67,320	4
2. Computer Specialists	254,537	20	513,863	28
Computer Scientists/Systems Analyst	93,200	15	200,684	22
Computer Programmers	161,337	23	313,179	31
*3. Engineering & Science Technicians	58,292	11	90,990	17
*Electronic Technicians	31,454	11	60,299	15
*Drafters	16,963	7	16,726	16
4. Computer Operators	117,000	29	408,475	59
5. Data Entry Operators	272,570	90	378,094	92
*6. Production Workers	680,299	46	872,345	49
*Operatives, Fabricators, Transporters & Laborers	519,221	58	591,091	58
*Assemblers	158,191	74	208,284	72
*Electronic Assemblers	---	--	55,879	77
Data Processing Repairers	30,844	3	46,626	8

Percent of total employed labor force in computer-related occupations

1970	1980
2.0	2.5

SOURCE:
*Only within Computers/Semiconductors Industry: Data from U.S. Census, Population Characteristics Special Report, Occupation by Industry for 1970 Table 8, 1980 Table 4.

All other occupational groups are from all industries. Data from U.S. Census Subject Report: Occupation by Industry 1970 Table 8, 1980 Table 1.

TABLE II

Total Employed and Percentage Distribution by Race, Spanish Origin and Gender
in the Labor Force and in Three Computer Related Occupations
1980

	Total Labor Force	Computer Scientists/ Systems Analysts	Computer Programmers	Computer Operators	Data Entry Operators
Total Employed	97,639,355	200,684	313,179	408,475	378,094
White Men	50.0	71.3	62.2	33.9	5.7
White Women	36.0	19.5	26.5	49.5	71.3
Black Men	4.8	3.0	3.1	4.7	1.1
Black Women	4.8	1.7	2.5	6.9	15.1
Other Races	8.4	4.5	5.7	5.0	6.8
	100.0%	100.0%	100.0%	100.0%	100.0%
Spanish Origin* Men	3.0	1.8	1.9	2.4	.1
Spanish Origin Women	2.0	.1	.1	2.8	5.7
Not of Spanish Origin	95.0	98.1	98.0	94.2	94.8
	100.0%	100.0%	100.0%	100.0%	100.0

*Persons of Spanish Origin can be of any race.

SOURCE: U.S. Bureau of the Census 1980 Subject Report Occupation by Industry, Table 1.

TABLE III

Number Employed in High Tech Industries and Percent of All Employed in 1970-1980

	1970		1980	
	Number Employed	Percent of All Employed	Number Employed	Percent of All Employed
All Workers	4,557,000	6.5	6,060,000	6.4
All Women	1,254,000	5.0	2,026,000	5.1
All Men	3,303,000	7.4	4,034,000	7.4

SOURCE: U. S. Census, 1/1000 P.U.S. Tape, 1970 and 1980.

TABLE IV

Ocupational Distribution of Men and Women Employed in High Tech Industries and Non-High Tech Industries in 1970 and 1980

1970

	High Tech Industries		Non-High Tech Industries	
	Men	Women	Men	Women
Managers	10	3	13	5
Professional and Technical	28	6	12	16
Sales	3	<1	8	10
Clerical	9	36	7	33
Services	2	1	8	20
Production	48	55	37	14
Other	2	<1	13	1
	100%	100%	100%	100%
N (in thousands)	3,195	1,205	39,357	23,676

1980

	High Tech Industries		Non-High Tech Industries	
	Men	Women	Men	Women
Managers	14	6	13	8
Professional and Technical	26	10	13	18
Sales	3	1	10	11
Clerical	8	35	7	31
Services	3	2	9	18
Production	44	46	35	11
Other	3	1	12	2
	100%	100%	100%	100%
N (in thousands)	4,034	2,026	50,263	37,729

SOURCE: U. S. Census, 1/1000 P.U.S. Tape, 1970 and 1980.

TABLE V

Employment and Earnings for Men and Women in Three Computer-Related Occupations in All Industries 1970 and 1980

	Total Number Employed (in 1000's)		Percent Women Employed		Mean Annual Earnings			
	1970	1980	1970	1980	1970 Men's Mean Erngs	F/M Ratio	1980 Men's Mean Erngs	F/M Ratio
Computer Specialists	254,537	513,863	20	28	$11,004	.71	$20,090	.72
Computer Scientists/ Systems Analysts	93,200	200,684	15	22	n.a.	n.a.	23,405	.73
Computer Programmers	161,377	313,179	23	31	n.a.	n.a.	17,967	.73
Computer Operators	117,000	408,475	29	59	n.a.	n.a.	14,203	.65

SOURCE: U. S. Bureau of the Census, 1980 Subject Report, Occupation by Industry, Table 1; and 1970 Subject Report, Occupation by Industry, Table .

n.a. not available

TABLE VI

Employment and Earnings for Men and Women
in Three Computer-Related Occupations in All Industries
1970 and 1980
Based on U.S. Census 1/1000 Samples

	Total Number Employed (sample size)		Median Annual Earnings			
			1970		1980	
	1970	1980	Men's Median Erngs	F/M Ratio	Men's Median Erngs	F/M Ratio
Computer Scientists/ Systems Analyst	105	199	$5.17	.75	$10.19	.74
Computer Programmers/	155	312	$4.10	.85	$ 8.12	.83
Computer Operators	106	456	$3.15	.63	$ 6.38	.69

SOURCE: U. S. Census, 1/1000 P.U.S. Tape, 1970 and 1980

TABLE VII

Occupations with Highest Median Weekly Earnings for Women Employed Full Time in Wage and Salary Work,[a] 1981 Annual Averages

Occupational Title[b]	Female Earnings
Operations & Systems Researchers & Analysts	$422
Computer Systems Analysts	420
Lawyers	407
Physicians, Dentists & Related Practitioners	401
Social Scientists	391
Teachers, College & University	389
Postal Clerks	382
Engineers	371
Ticket, Station & Express Agents	370
School Administrators, Elementary & Secondary	363
Life & Physical Scientists	357
Health Administrators	357
Public Administration Officials ano Administrators, Not Elsewhere Classified	337
Vocational & Educational Counselors	336
Registered Nurses	331
Personnel & Labor Relations Workers	330
Computer Programmers	329
Editors & Reporters	324
Secondary Schoolteachers	321
Librarians	318

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[a] Excludes earnings from self-employment

[b] Occupations listed are those in which female employment was 50,000 or more in 1981.

SOURCE: Current Population Survey, 1981 (Rytina, 1982)

TABLE VIII

Earnings Regressions for Computer Scientists/ Systems Analysts, Computer Programmers, and Computer Operators 1970 and 1980

	Computer Scientists/Systems Analysts		
	Mean	(Std. Dev.)	B
1970:			
Ln. of Hourly Earnings	1.7	(.44)	
Education: Up to 8 Years	.01	(.10)	.53
Some High School	.02	(.14)	-.23
High School	.29	(.45)	-.05
BA or BS	.23	(.42)	.26**
More than BA/BS	.22	(.42)	.15
Age	34.69	(9.77)	.07***
Age^2	1297.66	(797.95)	-.006**
Gender (=1 if Female)	.14	(.35)	-.07
High Tech Industry	.29	(.45)	.13
Constant			.02
N	105		
Adj. R^2	.20		
1980:			
Ln. of Hourly Earnings	2.16	(.63)	
Education: Up to 8 Years	0	(0)	-
Some High School	.01	(.07)	.21
High School	.13	(.33)	.14
BA or BS	.31	(.46)	.27**
More than BA/BS	.27	(.45)	.15
Age	34.58	(8.39)	.09**
Age^2	1265.98	(637.18)	-.001**
Gender (=1 if Female)	.25	(.43)	-.20*
High Tech Industry	.44	(.50)	.06
Constant			.10
N	199		
Adj. R^2	.10		

TABLE VIII--Page 2

	Computer Programmers		
	Mean	(Std. Dev.)	B
1970:			
Ln. of Hourly Earnings	1.30	(.79)	
Education: Up to 8 Years	0	0	-
Some High School	.02	(.14)	.29
High School	.23	(.42)	.09
BA or BS	.37	(.49)	.07
More than BA/BS	.07	(.26)	.04
Age	29.65	(8.05)	.04
Age^2	943.52	(568.57)	-.0002
Gender (=1 if Female)	.32	(.47)	-.16
High Tech Industry	.36	(.48)	.05
Constant			.50
N	155		
Adj. R^2	-.01		
1980:			
Ln. of Hourly Earnings	2.01	(.57)	
Education: Up to 8 Years	0	(0)	-
Some High School	.02	(.15)	-.16
High School	.17	(.38)	-.006
BA or BS	.31	(.46)	.22***
More than BA/BS	.15	(.36)	.24***
Age	32.28	(8.76)	.10***
Age^2	1118.15	(656.98)	-.001***
Gender (=1 if Female)	.29	(.45)	-.12*
High Tech Industry	.32	(.47)	.04
Constant			-.13
N	312		
Adj. R^2	.20		

TABLE VIII--Page 3

Computer Operators

	Mean	(Std. Dev.)	B
1970:			
Ln. of Hourly Earnings	1.16	(.67)	
Education: Up to 8 Years	.01	(.10)	-.14
Some High School	.07	(.25)	-.12
High School	.53	(.50)	.02
BA or BS	.01	(.10)	.77
More than BA/BS	.01	(.10)	.12
Age	28.80	(9.40)	.04
Age^2	917.07	(675.91)	-.0004
Gender (=1 if Female)	.21	(.41)	-.70***
High Tech Industry	.25	(.43)	-.10
Constant			.51
N	106		
Adj. R^2	.16		
1980:			
Ln. of Hourly Earnings	1.70	(.58)	
Education: Up to 8 Years	.01	(.10)	.01
Some High School	.04	(.19)	-.16
High School	.48	.50	-.01
BA or BS	.11	(.31)	.04
More than BA/BS	.02	(.15)	.09
Age	32.08	(10.77)	.06***
Age^2	1145.03	(812.62)	-.001***
Gender (=1 if Female)	.53	(.50)	-.27***
High Tech Industry	.20	.40	.18***
Constant			.59
N	456		
Adj. R^2	.20		

*p<.10
**p<.05
***p<.01

SOURCE: U.S. Census P.U.S. tapes, 1/1000 samples for 1970 and 1980.

TABLE IX

Three Computer-Related Occupations in All Industries, Electronic Computing Equipment Manufacturing and in Selected Major Industry Groups in 1980

COMPUTER SCIENTISTS/SYSTEMS ANALYSTS

	Total Employment	Percent Women	Men's Mean Annual Earnings	Ratio of F/M Earnings
All Industries	200,684	22.3	$23,405	.73
Electronic Computing Equipment Manufacturing	22,129	14.9	NA	NA
Mining	2,159	16.9	26,031	.77
Construction	1,500	22.3	22,661	.70
Manufacturing	65,606	17.5	24,093	.69
Transportation, Communications and Public Utilities	12,947	26.8	23,812	.82
Wholesale Trade	8,953	21.4	22,840	.80
Retail Trade	5,336	26.5	22,195	.71
Finance, Insurance and Real Estate	18,051	35.6	21,381	.78
Business Services	46,384	19.9	23,288	.74
Professional and Related Services	15,241	28.4	20,296	.68
Public Administration	23,415	24.4	24,991	.75

TABLE IX-Page 2

COMPUTER PROGRAMMERS

	Total Employment	Percent Women	Men's Mean Annual Earnings	Ratio of F/M Earnings
All Industries	313,179	31.1	$17,967	.73
Electronic Computing Equipment Manufacturing	22,702	22.0	NA	NA
Mining	3,171	32.5	19,455	.76
Construction	2,802	34.8	17,275	.69
Manufacturing	93,010	26.5	19,037	.75
Transportation, Communications and Public Utilities	22,537	34.9	19,704	.78
Wholesale Trade	11,477	32.1	18,064	.67
Retail Trade	10,052	33.6	16,400	.73
Finance, Insurance and Real Estate	39,749	36.6	16,774	.77
Business Services	63,423	28.0	17,826	.72
Professional and Related Services	35,352	34.3	12,353	.83
Public Administration	29,635	35.9	18,868	.74

TABLE IX-Page 3

COMPUTER OPERATORS

	Total Employment	Percent Women	Men's Mean Annual Earnings	Ratio of F/M Earnings
All Industries	408,475	59.0	$14,203	.65
Electronic Computing Equipment Manufacturing	7,175	46.6	NA	NA
Mining	4,647	42.9	16,041	.63
Construction	5,758	68.8	14,833	.67
Manufacturing	98,886	55.3	16,079	.63
Transportation, Communications and Public Utilities	35,852	56.7	17,067	.69
Wholesale Trade	30,876	73.2	14,213	.64
Retail Trade	26,140	67.4	13,026	.62
Finance, Insurance and Real Estate	63,660	57.3	12,878	.66
Business Services	43,697	45.8	13,010	.65
Professional and Related Services	54,466	67.2	10,024	.80
Public Administration	39,185	59.3	15,237	.65

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IFG

Institute for Research on Educational Finance and Governance

SCHOOL OF EDUCATION STANFORD UNIVERSITY

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THE LABOR MARKET IN SILICON VALLEY AND ITS IMPLICATIONS FOR EDUCATION

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May 1985

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ABSTRACT

Santa Clara County, California, is a prime example of what high tech growth promises in terms of employment, salary structures, and educational requirements for those areas where high tech industry flourishes. We find a high degree of gender polarization in the electronics industry, where women are largely employed in relatively low-skilled jobs requiring little schooling and men are employed in jobs requiring very high levels of education. Yet, both groups do well, earnings-wise -- anglo men because of the high pay-off to higher education and anglo women because of the longer time worked during the year and the higher pay-off to higher education than in other sectors. We also find a high pay-off,in the county as a whole, to hispanics who complete high school and to those who complete some college. Our data show, however, that the slow growth of traditional manufacturing will hurt hispanic males more than any other group.

As the electronics industry grows and if firms hire more women into professional and managerial positions, increased polarization of the labor force in the county may be prevented, we argue, by translating economic pay-off signals in the labor market into school policies that (1) focus on bringing more girls and young women into science and math courses, steering them toward technical, college-level training, and (2) also focus on getting more hispanics into college. According to our estimates, such policies will not only reduce polarization, they will also be responding to the greatest economic pay-offs in the county's labor market.

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Santa Clara County is the home of Silicon Valley, with its high economic growth rates and large increases in employment. The county is the largest employment center in the San Francisco Bay Area, and third largest in the State of California. The foundations of Santa Clara County's economy are the new high tech firms. As the source of new ideas and products, they form the center of the nation's dynamic technology and communications industry. The county is an example of what high tech growth promises in terms of employment, salary structures, and educational requirements for those areas where high tech industry flourishes. It is also the home of financially-troubled public school districts searching for direction in a rapidly changing economy.

The purpose of this paper is to explore the nature of the labor market in Santa Clara County and its implications for education in the county and the surrounding area. By analyzing the structure of this local labor market, we can gain insight into the differences (if any) between the employment and salary structures of high-technology industries and those of more traditional manufacturing industries, as well as the differences between high tech and the county's overall labor market employment and pay structures. From such differences, we shall draw implications for the future demand for education in the County on the assumption that high tech industries continue to dominate future economic growth.

Our analysis not only estimates the earnings and employment structure of all those who work for wages and salaries in Santa Clara County and how this structure differs among industries, but also focuses on differences in pay and employment between women and men and between anglos and hispanics (the largest minority group in the county). We suggest that the labor market for men and women and for hispanics and anglos is generally quite different. Our study examines these differences in the county and particularly as they are manifested in the electronics industry.

The relevance of the results is not limited to Santa Clara County and the San Francisco Bay Area. Other regions of the country have or are developing their own "Silicon Valleys." It is likely that the employment and wage structure of the high technology industry in these other centers of growth is similar to what we find in Santa Clara County. And whereas the largest minority population in this case study is hispanic, other areas also have their minority populations. The labor market situation of those minority groups is probably not very different from what our results show for hispanics.

The Structure of Employment in the County

Job growth in Santa Clara County has been steady and rapid despite the 1981-1982 recession. The job structure in the county is also much more oriented to manufacturing than in the U.S. or California as a whole (see Table 1 and Economic Report of the President, 1985, Table B-37). In that sense, Santa Clara is not typical of the rest of the San Francisco Bay Area, the state, or the country. But the importance of the high tech industry makes Santa Clara a good example of where income structure and educational pay-offs may be headed in the future, particulary in the manufacturing sector.

According to a report by the Santa Clara County Economic Futures Committee,[1] the County should have an increase of more than 340,000 jobs by the year 2000, or a 45% rise over 1980. A projection made by the Center for the Continuing Study of the California Economy, cited by the report, shows that anywhere from 79,000 to 148,000 new jobs in manufacturing will be available in the County between 1981 - 1990 (depending on overall conditions in the U.S. economy); of these jobs, only 16,000 are in non-high tech manufacturing. So job growth is expected to be rapid, with high tech manufacturing as the most important economic sector.

If high technology manufacturing is the wave of the future, the employment and wage structure in that industry has special importance in assessing potential pressures on the local and state educational system.

We have used the 1/100 census sample for the state of California to draw a subsample of those who worked in Santa Clara County in 1980 and who were employed, earning wages and salaries (not self-employed). Tables 1 and 2 show the employment breakdown in the sample by industrial sector, ethnicity, and gender. Our definition of "electronics manufacturing" includes software services, in order to have a more general category of high technology production.[2] This makes our figures for those employed in manufacturing somewhat larger than they should be in a stricter definition. Blacks in the sample were excluded because their small numbers precluded any statistically significant analysis.

One of the most important issues surrounding the changing type of manufacturing in the United States is the change in employment patterns within the manufacturing sector. As the electronics and defense industries grow relative to traditional manufacturing, can we expect significant changes in who is employed in the industry? Our Santa Clara County results suggest that we can.

The difference in the gender and ethnic employment structure in different parts of the manufacturing sector of the county is striking. Traditional manufacturing is almost three-fourths male, but a significant portion of those are hispanic males. Defense manufacturing is almost three-fourths anglo males, with a very small percentage of hispanics, considerably less than the 15 percent of total employees they represent in the sample. And the electronics part of the industry (62 percent of manufacturing employment in the County) is only 58 percent male and almost 42 percent female, approximately the same gender breakdown as in wholesale/retail trade (see Table 2).

Except for defense manufacturing, which employs about 6 percent of all wage-earners working in the county, the sectors that have been growing rapidly in the last 20 years, including electronics manufacturing, are much more feminized than traditional manufacturing. Professional services, for example, are also highly feminized, and have an underrepresentation of hispanics. But slow-growing and even declining traditional manufacturing has a much higher percentage of hispanic males working in it than the more rapidly growing sectors. Thus, hispanic (minority, lower education) males are least favored by present employment growth trends in the County, suggesting that the changes in the manufacturing sector nationwide auger badly for minority males in particular and probably less-educated males in general.

Santa Clara's Earnings Structure

The structure of incomes in Santa Clara County and the monetary return to years of schooling for those who have jobs in the county can give us important insights into the potential demand for schooling by those entering the local labor market. One of the fundamentals of post-World War II U.S. economic policy is that "a rising tide lifts all boats." Santa Clara County's growth rate in recent years has been one of the highest in the country and its unemployment rate one of the lowest (3.5 - 4.0 percent). How do the earnings of the lowest education groups, of minorities, and of women in the county compare to those of the U.S. as a whole? If the rising tide thesis is correct, these earnings should be significantly higher than in the rest of the country when adjusted for the county's higher cost of living.

An especially powerful version of the rising tide concept is that the lowest-paid workers in the economy gain in relative as well as actual terms if the unemployment rate is low and growth rapid. Chiswick and Mincer,[3] for example, argue that the most important factor reducing earnings inequality in the United States in the post-war period has been lower unemployment rates.

As a rough test of this thesis, we estimated arithmetic mean earnings (wages and salaries) for employed labor in the U.S. as a whole and in Santa Clara County for two age cohorts: 30 year-olds and 40 year-olds.[4] Average earnings in Santa Clara County for those anglo males who worked in 1979 tended to be somewhat higher than for the country as a whole, especially for somewhat older workers. Both anglo and hispanic females, especially the young and lower educated, earned substantially more in the county than nationally. Part of the higher earnings for males and females could reflect the significantly higher cost of living in the Bay Area compared to other regions of the country, but it does appear that the rising tide did lift many boats. Since 1979 was a year of moderately strong real growth nationally (2.8 percent) and relatively low unemployment (5.8 percent), the earnings differences in Tables 3 and 4 are probably lower than they were in 1980-83 when economic growth in Santa Clara County was rapid and real growth nationally averaged a low 0.9 percent annually (Economic Report of the President, 1985, Table B-2).

Hispanic males were the one group in the county that generally (except for high school graduates) earned the same or less than their counterparts in the rest of the U.S. This raises questions about the nature of the rising tide. Do higher growth rates (and lower unemployment rates) benefit everyone in this period of industrial restructuring? Our estimates from the census data suggest that anglo males and anglo and hispanic females' earnings were not higher in Santa Clara County because wage-earners in the county worked longer hours per week or more weeks per year than national averages in 1979.

Average time worked was essentially equal for corresponding sex/ethnic/education/age groups in the county and national samples. In the rising tide thesis, higher growth and lower unemployment rates would generally translate into higher earnings through increased time worked. In this case, the tide rose for women but not for hispanic males, suggesting that the rapid increase in employment in the county tended to be selective because of the changes in the structure of employment toward electronics manufacturing and business services and away from traditional manufacturing. Thus, higher earnings in the county, at least in 1979, may be better explained by the more rapid growth of a particular set of industries rather than more rapid growth in general. As we shall demonstrate, the job market for women and highly educated males has indeed produced a market for jobs with rather special characteristics.

The earnings comparison also suggests that the rising tide, structural employment changes, or both have not increased the earnings of anglo women in Santa Clara relative to anglo men. That is, despite changes in the shift of manufacturing in the county from traditional to high-tech industry that appear to have increased the number of jobs more rapidly for women than for men, women's earnings relative to men's in the county are approximately the same as in the rest of the country.

The data in Table 5 suggest why. Geometric mean earnings[5] are higher in the electronics industry than the average for the county, but the labor force in electronics is more polarized, gender-wise, than in the county's other employment sectors. More than 55 percent of the anglo females working in the industry versus only 22 percent of anglo males have completed high school or less. The figures for all sectors in the county are 50 percent for females and 38 percent for males, and in non-electronic, non-defense, manufacturing, 57 percent for females and 50 percent for males.

At the other end of the spectrum, 49 percent of the anglo males in the electronics industry have completed 4 years of college or more, compared to less than 13 percent of the anglo females. The figures of men and women completing college or more for the county as a whole are 35 and 22 percent, and in traditional manufacturing, 22 and 18 percent. If the electronics industry is the most rapidly growing sector in the county, the employment implications for males and females are very different: the great increase in jobs in the county has so far been primarily for well-educated males and less-educated females.

Other studies of employment in the computer industry show that women's earnings in computer-related occupations are lower than men's, taking account of education differences.[6] But we suggest that in addition to that type of discrimination within particular high-tech occupations, the electronics industry also divides the types of employment into which it hires men and women on educational grounds. If the demand for educated females is to change significantly in the county, it will probably have to be by increasing the employment in the electronics industry of college-educated women relative to college-educated males, and hiring those women into professional and managerial jobs.

Yet, whereas females working in electronics face wage discrimination even in particular occupations[7] and have a lower average level of schooling than in the county as whole, they tend to earn more in electronics. How do women do better, income-wise, in that industry? Table 5 suggests that such higher earnings can be explained by the greater amount of time women get to work in that sector as compared to women working elsewhere. We shall demonstrate this in a more systematic way below.

The low education level hispanics working in the county is also striking. A very high percentage of hispanic males and females have never finished high school: whereas 35 percent of anglo males and 22 percent of anglo females finished college (or more), this percentage drops to 10 percent for hispanic males and only 4.5 percent for hispanic females. Hispanic females also average even fewer hours of work per week and weeks per year than anglo females, further reducing hispanic female earnings.

The Economic Payoff to Education in Santa Clara County

What are the pay-offs to education in Santa Clara County, and how do these differ by gender and ethnic group? If we know the structure of earnings in the county, we can get a clearer picture of the potential pressures on its educational system.

In order to do this, we estimated Ordinary Least Squares (OLS) regression equations that relate wage and salary earnings of those employed to their age and educational level separately for each gender and ethnic group. We then estimated regression equations for each gender/ethnic group that included dichotomous (0 or 1) variables for each of 12 economic sectors in the county. In a third set of regression estimates, we included as variables the time worked by employees (hours worked per week and weeks worked per year) in addition to all the above variables. We also estimated separate equations for those working in the electronics industry and in traditional manufacturing (excluding defense industry).

From these estimates (available from the author on request), it is possible to calculate an estimated geometric mean earnings (we use geometric rather than arithmetic means to reduce the effect of extremely high earnings) of those in the sample of different ages and education levels.

Table 6 shows these estimated means at age 30 and 35 of those in the sample, by education level and gender/ethnic group. We have presented the results for two age groups primarily to show the effect of age on earnings rather than showing how much young and old workers earn in absolute terms. We also estimate geometric mean earnings for the electronics industry and traditional manufacturing.

The results indicate that differences in earnings between men and women persist across education groups, although differences are smaller for women who have completed high school and some college. For anglo women who have completed four years of college or more, the disadvantage increases. Education differences between men and women working in the county are therefore not the principal reason that their earnings differ. However, it is clear from Table 6 that differences in earnings between hispanic and anglo males with the same level of schooling are small except for those who have not completed high school. Thus, part of the large difference in overall mean earnings (Table 5) between hispanic and anglo males in the County ($6,750 versus $12,600) results from the much lower level of schooling for hispanics.

The pay-off to completing high school is large for anglo females and for all hispanics, but apparently not as great to anglo males. Conversely, the pay-off to taking some years of college is high for hispanic and anglo males and for hispanic females but not for anglo females. For anglo females the gain from completing college comes only if they go on to graduate or professional school. We can say little about the economic value to hispanics in the county of completing four years of college because of the small number in the sample with that level. However, the arithmetic means presented in Table 3 show that the return to hispanics completing college education nationwide is probably somewhat less than to the corresponding anglo gender group.

The earnings of those who work in the electronics industry and traditional manufacturing are considerably higher than the average for all wage-earners of the corresponding gender group in the county. This is especially true for women with college educations. College-educated women employed in the electronics industry appear -- at 30 years-old -- to earn salaries that correspond closely to the average earnings of college-educated men in the county labor force as a whole. But by age 35, earnings differences between college-educated men and women in electronics appear to widen. In traditional manufacturing, earnings for women with secondary education completed are essentially equal to those for men with the same level of schooling. Our sample of women in this industry is small, and so our estimates should be viewed with some care, but it appears that women with college education working in the sector are paid about the same as high school graduates, and perhaps less. Even so, the mean earnings of women with some college (but not graduated) compares favorably with male salaries in the sector, and are higher than those of women in electronics with some college education. Only women with graduate schooling working in electronics earn more. Nevertheless, a relatively small percentage of jobs in traditional manufacturing go to women.

The estimated age-earnings profile for women is much flatter than for men in the electronics industry. This is probably due partly to the withdrawal of many women from full-time work during the child-bearing and child-caring years, but it is also the result of the semi-skill, assembly and inspection jobs that most women have in electronics -- jobs not characterized by seniority wage increases. [Note, however, that these estimates are based on a cross-section survey. It may be that a longitudinal study would indicate similarly-sloped age-earnings curves for men and women in electronics because the industry is expanding so rapidly.]

Yet, even if age-earnings profiles were similar, only 44 percent of anglo women in the industry are college-educated, versus 62 percent of anglo men (Table 5). Therefore, although college-educated women get well paid in electronics, apparently higher-paid job opportunites are not as available for women as for men. A breakdown of occupations of men and women in electronics by level of schooling shows that only one-third of those anglo women who have taken some years of college (representing 32 percent of anglo women working in the industry), have professional or managerial/administrative jobs (Appendix A). The rest are clericals, or operatives. Sixty-four percent of the anglo men with the same education level are employed as professionals and managers. Thus, college education does not imply the same kind of jobs for women in electronics as for men. An alternative explanation is that fewer college-educated women get the kind of training required by professional and managerial jobs in electronics.

The regression estimates relating age and education to earnings suggest that earnings increase much more rapidly with age for both anglo males and females working in sectors outside of electronics than in that industry. Earnings rise much less rapidly with age for anglo women overall than for anglo men (even for those anglo men working in electronics), and for women working in electronics, age has hardly any significant effect on earnings at all. The age-earnings profile for women is especially steep in traditional manufacturing, steeper than for men, and much more of an influence on earnings than for women in other industries -- especially electronics. This is quite evident in Table 6, when we compare the earnings of females in electronics, 30 and 35 years-old and with 12 years of schooling, with the earnings of females in traditional manufacturing with the same schooling and the same age.

However, college education has a much higher payoff to anglo women in the electronics industry than in other economic sectors taken together or in traditional manufacturing, and graduate education for anglo males has a higher pay-off in electronics employment than in the rest of the labor force. Our estimates suggest, therefore, that seniority in the electronics industry as a basis for increased earnings is far less important than in other sectors, and education is more important. The expansion of the electronics industry relative to the rest of the economy tends, especially, to put more emphasis on rewards to higher education and so should increase the demand in the county for college-educated men. For women, however, it provides a mixed blessing: the rewards to college completion are higher, but professional and managerial job opportunities are fewer, than in the rest of the economy.

There were not enough hispanic males and females who work in electronics in the county sample to do a systematic analysis of their earnings in that industry. However, the regression estimates for all hispanic male and female wage-earners in the county indicate that unlike anglos, female hispanics do not have age-earnings profiles that are flatter than the hispanic males in the sample. And hispanic females have relatively higher income gains with higher age than anglo females, and apparently have a relatively higher pay-off to completing high school and to taking some years of college than do hispanic males or anglo males and females. This is also evidenced by the figures in Table 6. Most hispanic females in the county in 1980 had completed high school or less and were paid the lowest wages of any of the groups under study. Yet, the high relative pay-offs to additional schooling for hispanic females suggests that this group should be demanding more schooling in the future, and that this demand should be felt largely at the levels of completing secondary education and taking some years of college.

Thus far, our estimates have assumed that the principal variables explaining earnings variation among wage earners of the same gender and ethnic group are age and education. This assumes a direct relation between the education and age that an employee has and the value that the employer places on those two variables. We have compared some different sectors of the economy, focusing on the electronics industry and traditional manufacturing. These comparisons show that, taking account of education and age differences, average earnings and the pay-off to higher education for anglo women are significantly higher in electronics than in traditional manufacturing and than in the county as a whole.

Nevertheless, we have not yet included a more detailed analysis of the effect on earnings of possible differences in pay scales in various economic sectors. Neither have we discussed the effect on estimated mean annual earnings of hours and weeks worked during the year.

Including the effect of economic sector in the regression estimates, we find that those age and education coefficients that were significantly different from zero in the original estimates change little in all four gender/ethnic groups. This suggests that education and age are not distributed across industries in such a way that earnings variation is explained primarily by economic sector wage policies rather than the value placed by all sectors on education and age as a basis for salary differentials. But while this finding holds true in general, the regression estimates show that the pay-off to graduate education increases for anglo males when sector variables are included, indicating that a disproportionate percentage of those with graduate education are in lower-paying professional services. The estimates also show that including sector reduces the estimated return to the college (but not graduate school) for anglo women, although these coefficients were not statistically significant even when sector was not included. The results for hispanics are less clear because of problems with statistical significance, but it does appear that hispanic females with incomplete high school working in the electronics industry are paid much higher salaries than those in other sectors. Taking account of the electronics variable therefore increases the return to completing high school for hispanic females.

Once the regression estimates include time worked -- in the form of variables measuring hours worked per week and weeks worked per year -- the effect of age on earnings is sharply reduced (see Regression III results in Appendix A) for all gender and ethnic groups. Only in the case of anglo males does the age coefficient even remain statistically significant.

The coefficients of the education variables for anglo males and females change little when time worked is included, except in the case of less than high school completed. For hispanics, however, including time worked eliminates the influence of both education and age on earnings.

By including time worked, education, economic sector, and age variables in the estimates, the differences in earnings associated with different economic sectors are corrected for differences among sectors in time worked and the age and education of those employed in each sector. We find that the relatively higher-paying economic sectors in the county are, for anglo males, construction and all three sub-sectors of manufacturing (with electronics the lowest of the three), construction for hispanic males, professional services for both anglo and hispanic females, and, in addition, business and repair services for anglo females. The only significantly lower-paying sector is personal services for anglo males.

Time worked during the year is therefore a key variable in explaining earnings variation generally in the county and is crucial in explaining why women who work in the electronics industry earn more than in other sectors. Time worked is also important in explaining the higher earnings of high school completers over drop-outs in all gender and ethnic groups, and even explains part of the higher earnings of college-educated hispanics compared to those hispanics who complete only high school.

When we add that the return to some college education (short-of-graduation) for anglo females may also be explained by more hours and weeks worked compared to anglo females completing high school, this means that for more than 60 percent of the labor force (all but college-educated anglo males and college graduate anglo females) in the county, time worked is the principal variable governing earnings. Higher education and age are apparently the means to get jobs that require or allow more hours worked per week and more weeks worked per year. Indeed, an industry like electronics that pays significantly higher salaries to women, also appears to do so primarily through providing more hours of work per year than by paying higher wages per hour.

The significant correlation between age and time worked for women suggests that more than for men, time worked acts as a classifier of work roles for younger and older women.

Another way to measure the effect of time worked per year on salary differences relative to education differences is to estimate male and female earnings assuming that they work the same number of hours per week and weeks per year and to estimate these earnings assuming that they have equal education. We also perform the same estimates comparing anglo and hispanic males, and anglo and hispanic females.

The results of these estimates are shown in Table 7. They show the importance of time worked in explaining the difference in earnings between anglo males and other groups. In each case, the regression estimates were used to simulate hypothetical earnings for anglo females and hispanic males and females -- earnings based on the assumption that individuals in each of these groups worked the same number of hours per week and weeks per year as the mean hours and weeks worked by anglo males. Similarly, hypothetical earnings were estimated on the assumption that the distribution of education was the same as for anglo males. In one of the comparisons, the same type of calculation was made assuming time worked and education distribution for hispanic females was equal to anglo females.

We can see that if anglo females and hispanic males and females worked the same hours and weeks that anglo males, much of the average earnings differences between them in the county would be eliminated. Education equalization has a much smaller effect on equalizing earnings than equalizing time worked, except between anglo and hispanic females. The results imply that conditions in the labor market itself are much more important in explaining earnings differences between gender and ethnic groups in the county than educational differences between those groups.

Nevertheless, the hispanic/anglo male comparison is strongly affected by the large proportion of hispanic males in the sample who have not completed high school. Table 6 suggests that those hispanic males with completed high school or more, have earnings that are almost equal to those of anglo males. Yet, Table 7 indicates that the impact on earnings of completing high school is contained largely in a time worked effect, or, it could be argued, in access to jobs that are more likely to be full-time, full-year and that are not marked by high rates of unemployment. In electronics, however, although time worked is crucial to explaining differences in earnings between males and females, educational differences are almost as important. This distinguishes the high-tech sector sharply from others, where educational composition of males and females working in the sector accounts for little of earnings differences. Three-quarters of the difference in earnings in electronics is due to time worked plus education differences.

Implications for Schooling

Santa Clara County's labor market differs substantially from the national employment structure. The report by the County's

Economic Futures Committee suggests that the County's expansion over the next decade will be more rapid than national trends, and may even be able to continue to grow through recessionary periods, as it did in 1981-82.

Our results for the Santa Clara County labor market suggest that the expansion of the high technology (electronics) industry, even though it is expected to slow somewhat in the future, will continue to provide increased demand for highly educated labor that already commands and should continue to receive higher than average salaries. The difference in salaries paid in electronics to the better educated is especially evident in the case of women: college-educated women earn more in electronics because they work more hours per year there than in other sectors. The effect of these higher salaries should provide a particularly great incentive for women to get into the electronics industry, and, in order to increase the probability of obtaining jobs there, to go into engineering and other technical fields requiring college education. If young women respond to these economic signals, secondary schools in the county will be called upon increasingly to provide science and math college preparation for women.

More than any other group, hispanic males in the County will be hurt by the relative decline of traditional manufacturing. It is in that industry and construction that this gender/ethnic group has obtained access to higher incomes. The slow growth of traditional manufacturing could reduce the presently very high return to hispanic males in the county. However, the rapid growth of other jobs requiring completion of secondary education, and the high return to taking some years of college education (Table 6) should keep the value to all hispanics of completing secondary school very high.

If economic incentives mean anything, hispanics of both sexes should also be pressuring to complete high school, without necessarily going on to college. Yet, the high return for hispanics to continue on to college (a higher return overall than for anglo females), should also push hispanics to demand more college track courses and college counseling. The question is whether Santa Clara secondary schools are prepared to provide high quality education for hispanics to take advantage of the high returns to taking some years of college or even completing high school. It also raises the question of what the school system is doing to convey to hispanics the value and possibilities of going on to college.

In sum, it appears from our analysis that the greatest relative pay-offs to those now in secondary education in the county are for hispanics to complete a high school degree and to take courses that will allow them to go on to college, and for young women to go to college and then find jobs in the electronics industry. The opportunity for finding work in electronics should be much greater if young women take their training in engineering and other technical fields that provide access to such jobs. But that, by itself, may not insure that more college-educated women will find high-level work in electronics: high-tech industry offers college-educated women higher earnings than other sectors of the economy, but also relatively fewer professional and managerial positions.

The same can be said of engineering and technical education for hispanics: hispanics of both genders should do well, earnings wise, going into technical fields at the college level. The difference this would make for young hispanic women would probably be greater than that for young men, but, as for anglo women, the potential high pay-off for college-educated hispanic women in electronics depends on whether they can get access to professional jobs.

County public schools will have to change significantly from the first grade or even kindergarten onwards if they are to respond to the labor market pay-offs shown in this analysis. A greater emphasis will have to be placed not just on science and math, as has been suggested by others, but on reaching girls with that science and math. Even more important, there will have to be a shift to preparing hispanic boys and girls -- the least successful group academically -- as early as possible in primary school for college entrance.

If these changes are not made in the schools, the expansion of high technology industry in Santa Clara County promises to increase the number of jobs, but also to exacerbate occupational and earnings polarization of the County's labor force.

NOTES

1. Santa Clara County. Report of the Economic Futures Committee, 1983 (mimeo).

2. Our definition of electronics, defense manufacturing, and "traditional manufacturing" are the following:

	Census Cat.	SIC Code	Name of Industry
Electron.:	321	357, exc. 3573	Office & Acct. Mach.
	322	3573	Electr. Comp. Equip.
	340	363	Household Appl.
	341	365, 366	Radio,TV,&Comm. Equip.
	342	361,362,364,367,369	Electr. Mach.,Equip. & Supplies, n.e.c.
	350		Not Spec. Electr. Mach., equip.& supp.
	371	381, 382	Scient.&Contr. Instrum.
	740	737	Computer&Data Proc.Serv.
Defense:	292	348	Ordnance
	352	372	Aircraft and Parts
	362	376	Guided Missiles, Space Veh., & Parts

Traditional Manufacturing is defined as all other census categories 100 through 291 and all other 300s.

3. Chiswick, B. and J. Mincer. "Time Series Changes in Personal Income Inequality in the United States from 1939, with Projections to 1985," Journal of Political Economy, 80, 3 (May/June 1972. pp. S34-S66.

4. Arithmetic means have the disadvantage of being unduly weighted by high "outlying" earnings, but they serve here as a first comparison. Later, we use geometric means to analyze these differences in more detail.

5. Geometric mean earnings estimated as the mean of 1979 log earnings. Log earnings are used to reduce the effect of high income "outliers" on the mean. The geometric mean is a close approximation to the median.

6. Strober, M. and C. Arnold. "Integrated Circuits/Segregated Labor: Women in Three Computer-Related Occupations," Stanford University. Institute for Research on Educational Finance and Governance, November, 1984, Project Report 84-A27.

7. Ibid, Table VIII.

Table 1

Santa Clara County Labor Market: Employment by Industrial Sector and Gender/Ethnic Group, 1980 (percent)

Gender/Ethnic Group

Industrial Sector	Anglo Males	Anglo Females	Hisp. Males	Hisp. Females	Total County	Total Calif.
Agric.& Min.	0.5	0.5	2.4	0.6	0.7	3.5
Construct.	5.6	0.4	6.7	1.3	3.4	5.6
Manuf.,total	45.2	29.9	40.2	40.7	38.7	20.3
Defense	7.2	2.7	2.4	2.6	4.8	
Electronics	26.6	21.2	18.2	31.0	24.1	
Other	11.4	6.0	19.6	7.1	9.8	
Transp.& Comm.	5.6	3.2	7.2	2.6	4.6	7.1
Wholes./Retail	21.4	20.4	20.5	17.4	20.5	20.9
Financ. Serv.	2.0	7.5	1.9	7.4	4.4	7.1
Services, tot.	16.4	35.0	18.7	23.9	24.1	30.3
Bus.& Repair	4.2	3.3	4.8	3.2	3.8	5.4
Pers.&Entert.	1.5	3.5	2.4	3.9	2.5	4.9
Prof. Serv.	10.7	28.2	11.5	16.8	17.8	20.0
Public Adm.	3.3	3.1	2.4	5.8	3.3	5.1
Total # in Sample	1110	896	209	155	2370	
Percent of Sample	46.8	37.8	8.8	6.5	100.0	

Source: U.S. Census, Public Use 1/100 Sample, California, 1980. "Total California" column from California Department of Finance, Financial Research Section. California Statistical Abstract, 1983, Table C-1.

Table 2

Santa Clara County Labor Market: Employment of Gender Ethnic Groups, by Major Industrial Sector, 1980 (percent)

	Gender/Ethnic Group				
Industrial Sector	Anglo Males	Anglo Females	Hispanic Males	Hispanic Females	Total No. in Sample
Total County	46.8	37.8	8.8	6.5	2370 (100%)
Manuf., other	54.5	23.2	17.6	4.7	233 (100%)
Manuf., defense	70.8	21.2	4.4	3.5	113 (100%)
Manuf., electr.	51.7	33.2	6.6	8.4	572 (100%)
Wholesale/ Retail Trade	49.0	37.6	7.8	5.6	486 (100%)
Prof. Services	28.2	60.0	5.7	6.2	422 (100%)
Total in the Four Sectors	860 (77.5%)	704 (78.6%)	146 (69.8%)	116 (74.8%)	1826 (77.0%)

Source: U.S. Census, Public Use 1/100 California Sample, 1980.

Table 3

United States: Arithmetic Mean Earnings by Level of Education, Age and Sex/Race/Ethnic Group, 1979, Employed Only (current dollars)

		Level of Education/30 years-old			
Group	< HS Compl.	HS Compl.	Some College	College Complete	Grad. School
White Males	14,530	13,643	17,438	20,188	16,747
White Females	6,794	7,612	9,192	11,888	12,463
Black Males	6,551	11,608	10,556	13,775	14,852
Black Females	7,106	10,296	7,592	12,945	8,311
Hispanic Males	9,867	11,462	13,637	15,438	18,005
Hisp. Females	6,792	6,576	6,195	9,685	8,528
		40 years-old			
White Males	15,594	18,292	24,801	28,822	30,960
White Females	7,141	8,464	12,667	9,870	14,806
Black Males	11,147	14,193	19,326	24,005	20,938
Black Females	13,317	7,959	8,971	--	--
Hispanic Males	14,830	9,374	18,398	--	13,995
Hisp. Females	3,982	7,031	9,485	--	--

Source: U.S. Census, 1/1000 Public Use Sample, 1980

Table 4

Santa Clara County: Arithmetic Mean Earnings by Level of Education, Age and Sex/Ethnic/Race Group, 1979, Employed Only (current dollars)

	Educational Level/30 years-old				
Group	≤ HS Compl.	HS Compl.	Some College	Complete College	Grad School
White Males	15,750	17,091	17,891	19,627	21,589
White Females	9,126	9,585	11,683	12,719	12,540
Hispanic Males	8,845	18,444	13,196	12,941	18,582
Hisp. Females	7,032	9,616	9,743	21,505	--
			40 years-old		
White Males	22,065	22,065	25,523	35,036	34,298
White Females	8,347	9,997	12,451	12,719	12,540
Hispanic Males	14,387	20,359	18,972	14,252	23,605
Hisp. Females	7,957	6,616	11,907	--	--

Source: U.S. Census, California Public Use 1/100 Sample, 1980

Table 5

Santa Clara County Labor Market: Mean Age, Annual Earnings, Weeks and Hours Worked, and Distribution of Education, 1980

	Entire Sample				Electr. Manuf.	
Variable	Anglo Males	Anglo Females	Hisp. Males	Hisp. Females	Anglo Males	Anglo Females
Mean Earnings* (annual $)	12,597	5,831	6,752	3,627	18,841	9,275
Weeks Worked	46.8	42.7	42.6	39.8	49.2	46.6
Weekly Hours	39.9	34.2	38.1	33.8	41.6	39.2
Mean Age (yrs)	36.6	35.8	32.4	31.0	35.8	32.9
Education (%)						
Less than compl. hs	12.5	14.4	42.6	34.8	5.1	15.1
Compl. hs	25.5	36.0	38.7	35.5	17.3	40.4
Some coll.	26.8	27.7	18.7	25.2	28.1	31.6
Comp.coll.	16.2	10.4	5.7	3.2	26.1	7.4
Grad sch.	19.0	11.5	4.3	1.3	23.4	5.3

Source: 1/100 California Census Sample, 1980.

* 1979 geometric mean earnings estimated as the mean of log earnings. Log earnings are used to reduce the effect of high income "outliers" on the mean. The geometric mean is a close approximation to the median.

Table 6

Santa Clara County Labor Market: Estimated Geometric Mean Earnings at 30 and 35 Years of Age, by Schooling and Gender/Ethnic Group,1979 (dollars)

Sex/Ethnic	Level of Schooling/30 Years-old				
Group	Less than 12	12	13-15	16	17+
Anglo Males	8185	10977	13406	16983	16882
Anglo Females	3348	6102	7561	7325	8818
Hisp. Males	6095	10401	12644	**	15840
Hisp. Females	2261	5134	9758	18237	n.a.
Electronic Industry:					
Anglo Males	n.a.	12533	16655	18122	21498
Anglo Females	4233	7992	11330	13435	17680
Trad. Manuf.:					
Anglo Males	n.a.	13594	15013	21917	20098
Anglo Females	5118	13210	***	***	***
		35 Years-old			
Anglo Males	12308	16561	20226	25622	25474
Anglo Females	3992	7277	9016	8734	10515
Hisp. Males	8241	14063	17094	**	21416
Hisp. Females	3056	6938	13186	24644	n.a.
Electronic Industry:					
Anglo Males	n.a.	18376	24421	26572	41890
Anglo Females	4473	8528	12090	14336	18866
Trad. Manuf.					
Anglo Males	n.a.	19311	21326	31134	28550
Anglo Females	6543	16887	***	***	***

Source: U.S. Census, 1/100 California Public Use Sample, 1980.

** Estimates are very low ($2700 and $3600) and not statistically significant -- based on small sample size (11 hispanic males in the sample completed college). Small sample size also affects estimates for hispanic males with 17+ years of school and hispanic females with 16 and 17+ years.

*** Estimated earnings not significantly different from geometric mean for 12 years of schooling.

Table 7

Santa Clara County Labor Market: Earnings Comparisons Among Gender/Ethnic Groups Assuming Equal Time Worked and Equal Education, 1980

Comparison Groups	(1) Estimated Actual Income	(2) Equal Time Worked	(3) Equal Education	(3) Both Equal
Anglo Males/	12,597	12,597	12,597	12,597
Anglo Females	5,831	10,554	6,117	11,046
Anglo Males/	12,597	12,597	12,597	**
Hisp. Males	6,752	9,500	7,440	
Anglo Females/	5,831	5,831	5,831	**
Hisp. Females	3,627	4,654	4,800	
Anglo Males/	12,597	12,597	12,597	**
Hisp. Females	3,627	9,711	5,189	
Electronics:				
Anglo Males/	18,841	18,841	18,841	18,841
Anglo Females	9,275	13,023	12,444	16,342

Source: Column (1): Table 13; Column (2): Appendix A, regression estimates including time worked, economic sector, education, and age -- earnings of second group in each comparative pair estimated by multiplying coefficients of weeks worked and hours worked for second group times the average time worked of the first group in the pair; Column (3): regression estimates including education and age variables -- coefficients of education variable in regression estimate for second group multiplied times the mean education of the first group in pair; Column (4): same as column (2) but coefficients of both time worked and education of second group multiplied times mean values for those variables corresponding to the first group.

**Insufficient information in regression estimate to perform calculation.

APPENDIX A: TABLE 1

Santa Clara County: Anglo Males, Electronics Industry, Education Level and Occupation (percent)

	Education Level					
Occupation	≤ 12 yrs.	HS Compl.	Some College	Compl. College	Grad. School	Row Total
Professional-Tech.	6.7	19.6	48.2	54.5	55.1	44.4
Manager-Adm.	13.3	11.8	15.7	29.9	36.2	23.4
Sales	0.0	0.0	1.2	1.3	2.9	1.4
Clerical-Adm.	6.7	19.6	8.4	7.8	2.9	8.8
Crafts	26.7	21.6	16.9	2.6	2.9	11.2
Operatives	33.3	17.6	6.0	2.6	0.0	7.1
Transp. Oper.	6.7	3.9	1.2	0.0	0.0	1.4
Non-farm Lab.	0.0	2.0	2.4	0.0	0.0	1.0
Service Work.	6.7	3.9	0.0	1.3	0.0	1.4
Total %	100.0	100.0	100.0	100.0	100.0	100.0
Total number	15	51	83	77	69	295

Source: Public Use California 1/100 Sample, 1980

APPENDIX A: TABLE 2

Santa Clara County: Anglo Females, Electronics Industry, Education Level and Occupation (percent)

	Education Level					
Occupation	≤ 12 yrs.	HS Compl.	Some College	Compl. College	Grad. School	Total
Professional-Tech.	10.3	10.4	21.7	42.9	60.0	18.9
Manager-Adm.	0.0	9.1	13.3	21.4	10.0	10.0
Sales	0.0	3.9	0.0	7.1	0.0	2.1
Clerical-Adm.	31.0	33.8	48.3	14.3	20.0	35.8
Crafts	6.9	5.2	6.7	7.1	10.0	6.3
Operatives	51.7	36.4	10.0	0.0	0.0	25.8
Non-farm Lab.	0.0	1.3	0.0	7.1	0.0	1.1
Total %	100.0	100.0	100.0	100.0	100.0	100.0
Total number	29	77	60	14	10	190

Source: Public Use California 1/100 Sample, 1980